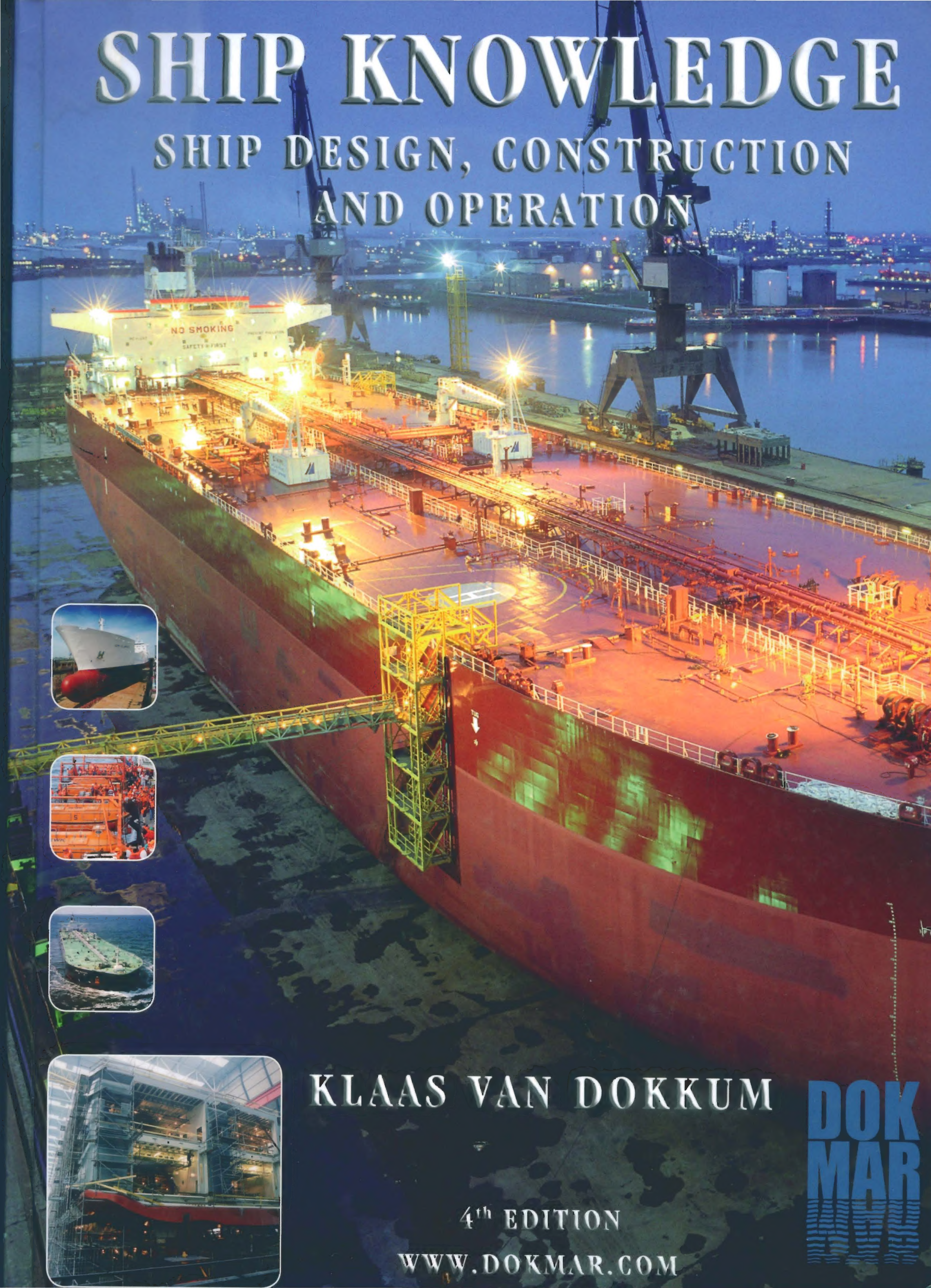

SHIP KNOWLEDGE

SHIP DESIGN, CONSTRUCTION AND OPERATION

KLAAS VAN DOKKUM

4th EDITION

WWW.DOKMAR.COM

Acknowledgements

I stand in great debt to the following persons for their invaluable cooperation:

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Chapter 11 part 1 and 2	Hans ten Katen	Naval Architect
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Introduction to the 4th edition.

In preparing the 4th English edition a number of inadequacies, omissions and defects of the 3rd edition have been remedied, some of the chapters have been considerably rewritten, many subjects have been improved and quite a lot of new ones have been added.

The various subjects pertaining to modern shipbuilding and seamanship as well as to present-day shipping trends and the offshore industry, are dealt with in this book in a very clear and detailed manner. An attempt is made to give as complete an overview of ships, pertinent auxiliaries, systems, rules and regulations as possible. The book provides a rich source of maritime information meant for all those with an interest in shipping. It is eminently suitable for maritime students and newcomers in the field. For those employed in shipbuilding, shipping and related fields, this book is an efficient reference and convenient manual.

In order to facilitate finding a certain word or subject, an index and list of abbriviations are included at the back of the book.
The author aims at forging a strong link between the contents of the book and the views of its readers, and any reactions, recommendations or criticism are highly welcome.

On the website http://www.dokmar.com/ you will find free downloads of questions pertaining to each chapter and an explanation of the abbreviations used is this book.

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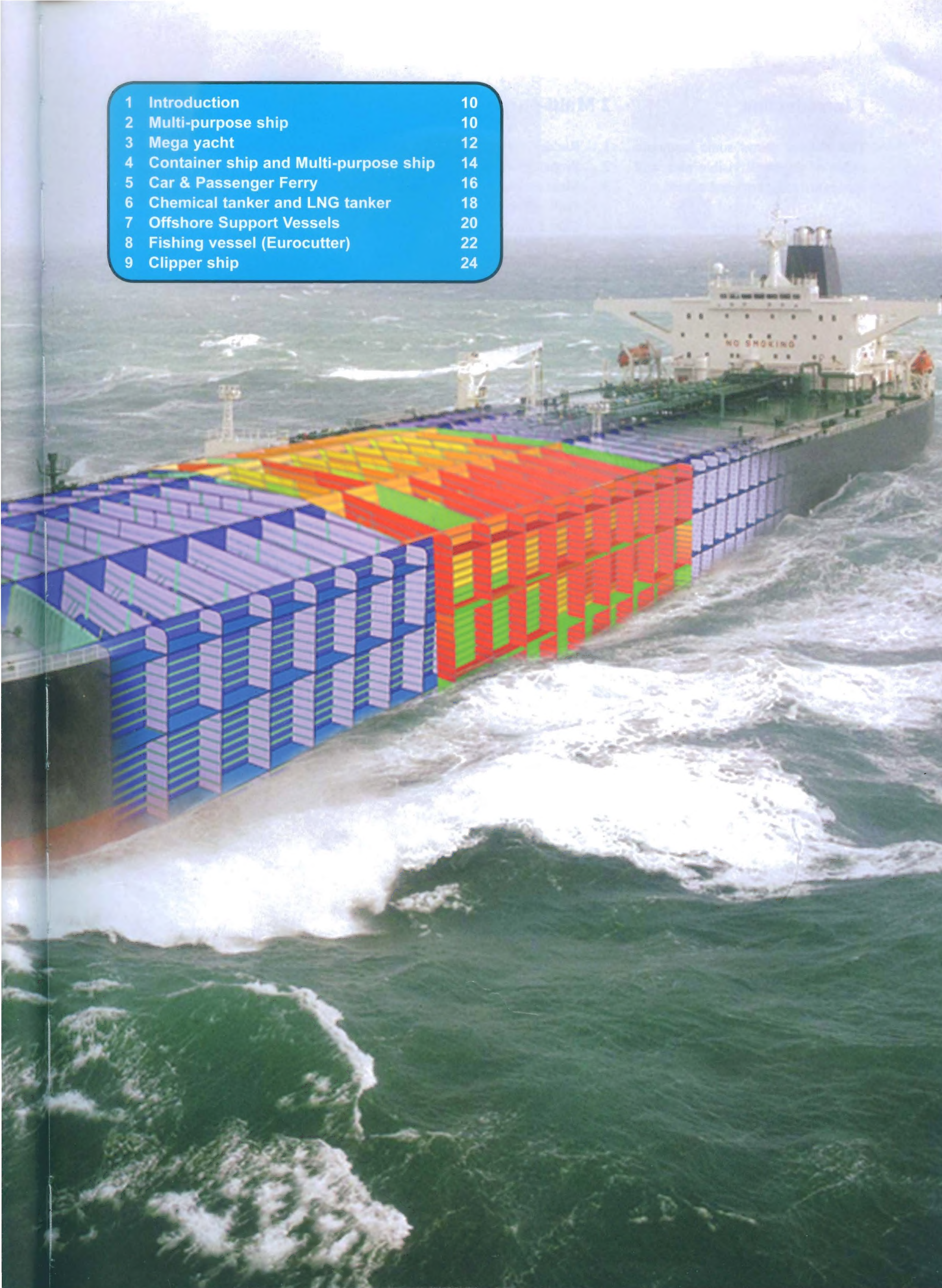
CHAPTER 1

Shipwise



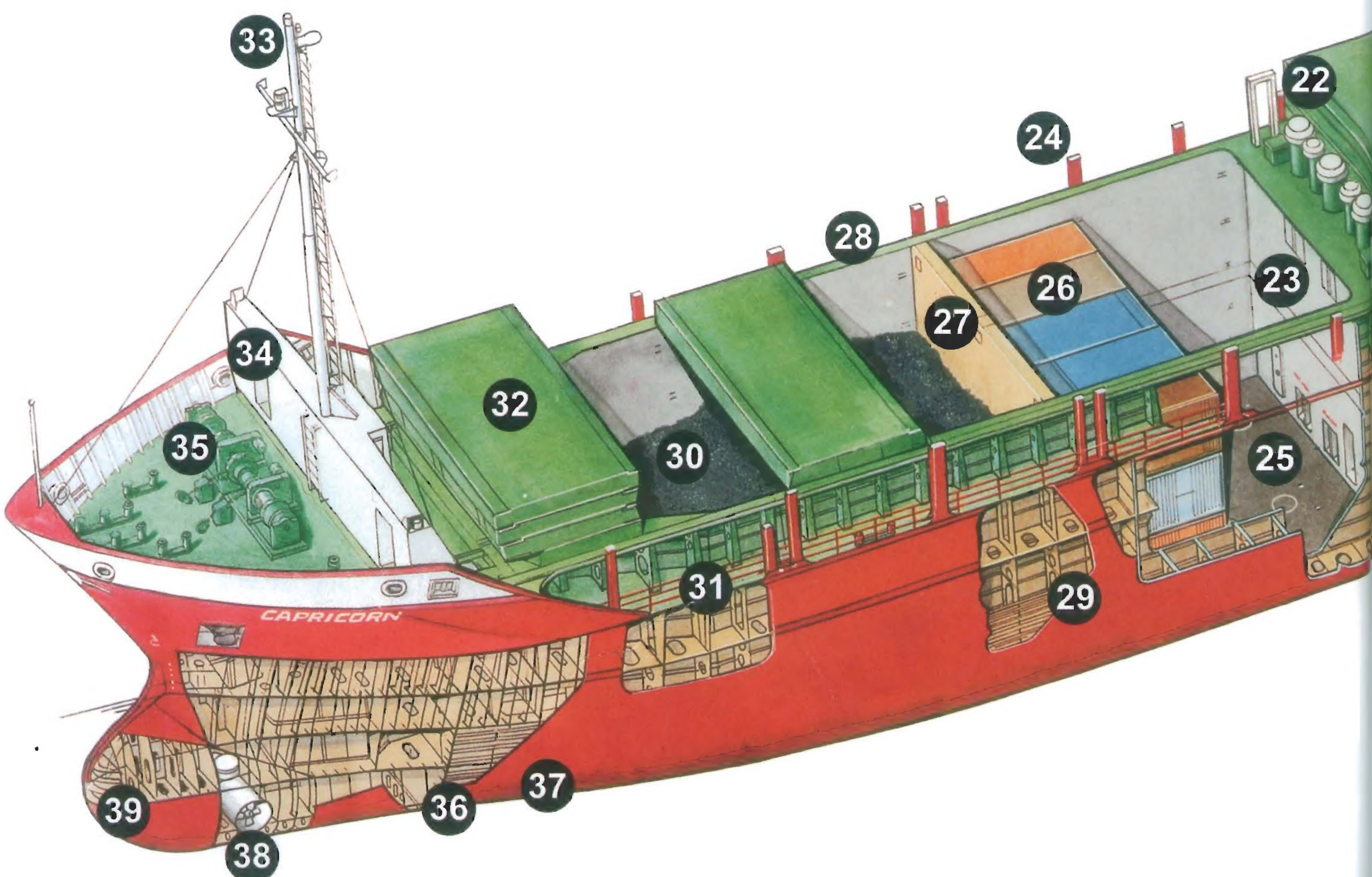
1 Introduction

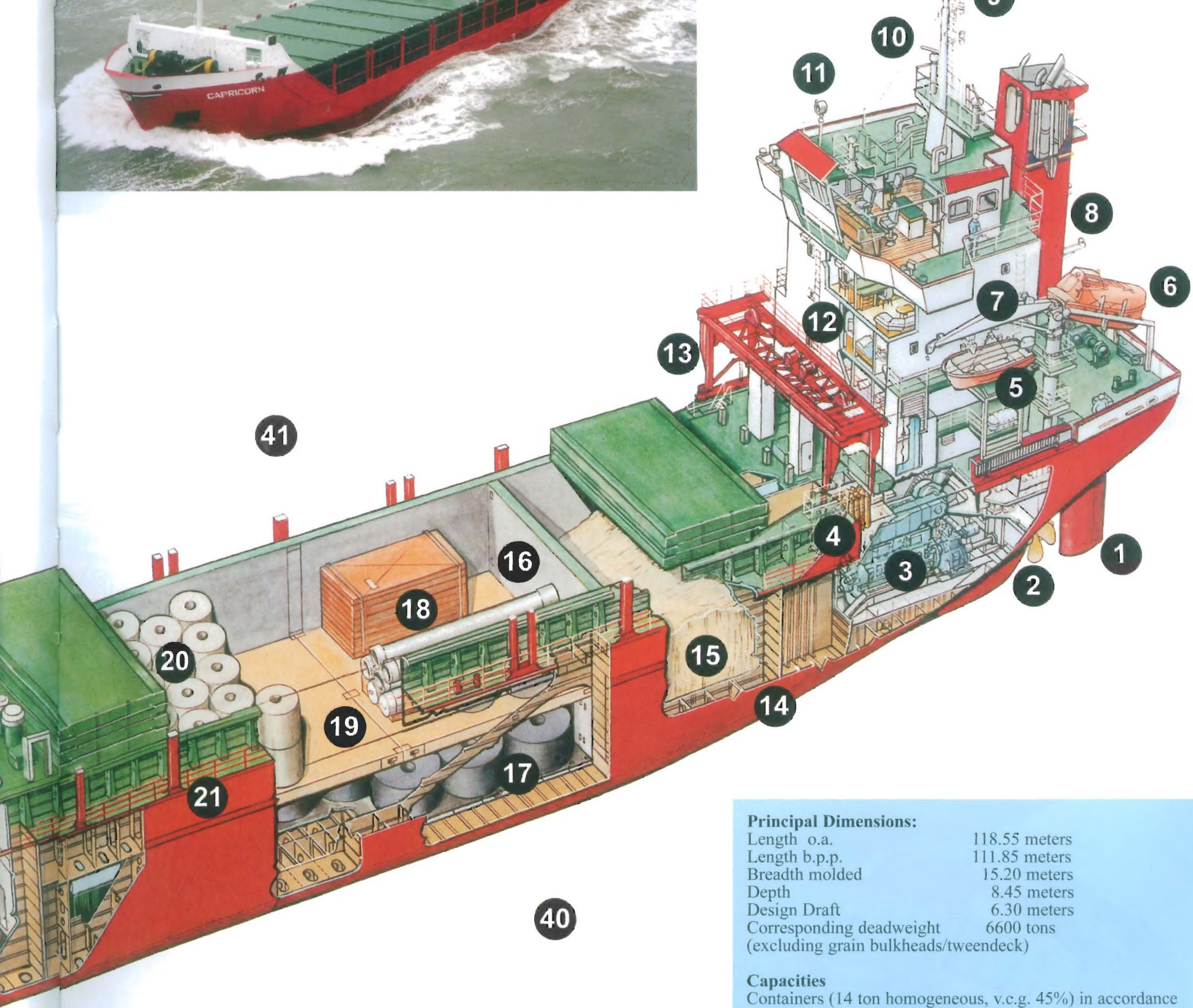
This chapter shows some isometric views of ships. All visible parts and spaces are numbered and named.

This is meant as an introduction to different types of ships and can be used as a reference for the following chapters. It can also be used as an indication of the size of a compartment relative to the whole ship.

2 Multi-purpose ship

1. Rudder
2. Propeller
3. Main engine with gearbox and shaft generator
4. CO_2 bottles in CO_2 room
5. Man overboard boat (MOB)
6. Free fall lifeboat
7. Crane for MOB, lifeboat, life raft and provisions.
8. Funnel with all exhaust pipes
9. Rear mast with navigation lights
10. Cross trees with radar scanners
11. Top deck with magnetic compass and search light
12. Accommodation
13. Hatch stacking crane
14. Heavy fuel oil tank
15. Bulk cargo
16. Vertical bulkhead or pontoon
17. Heavy cargo, steel coils
18. Project cargo
19. Horizontal decks or hatch covers
20. General cargo, rolls of paper
21. Sheer strake
22. Hold fan
23. Fixed bulkhead
24. Container pedestal
25. Tank top, max. load 15 t/m^2
26. Containers, 1 bay, 5 rows, 3 tiers
27. Vertical bulkhead or pontoon
28. Hatch coaming
29. Wing tank (ballast)
30. Bulk cargo
31. Gangway
32. Stacked hatches
33. Top light, range light
34. Breakwater
35. Anchor windlass
36. Collision bulkhead
37. Deep tank
38. Bow thruster in nozzle
39. Forepeak tank in bulbous bow
40. Port side
41. Starboard side





Principal Dimensions:

Length o.a.	118.55 meters
Length b.p.p.	111.85 meters
Breadth molded	15.20 meters
Depth	8.45 meters
Design Draft	6.30 meters
Corresponding deadweight	6600 tons

(excluding grain bulkheads/tweendeck)

Capacities

Containers (14 ton homogeneous, v.c.g. 45%) in accordance with ISO standard at mean draft of approximately 6.30 meter.

in hold	174 TEU (Twenty feet Equivalent Units)
on deck	96 TEU

Containers

in hold	174 TEU
on deck	242 TEU

Tonnage Regulation (London 1969)	4900 Gross Tonnage
Grain capacity (excluding bulkheads)	328500 Cubic Feet

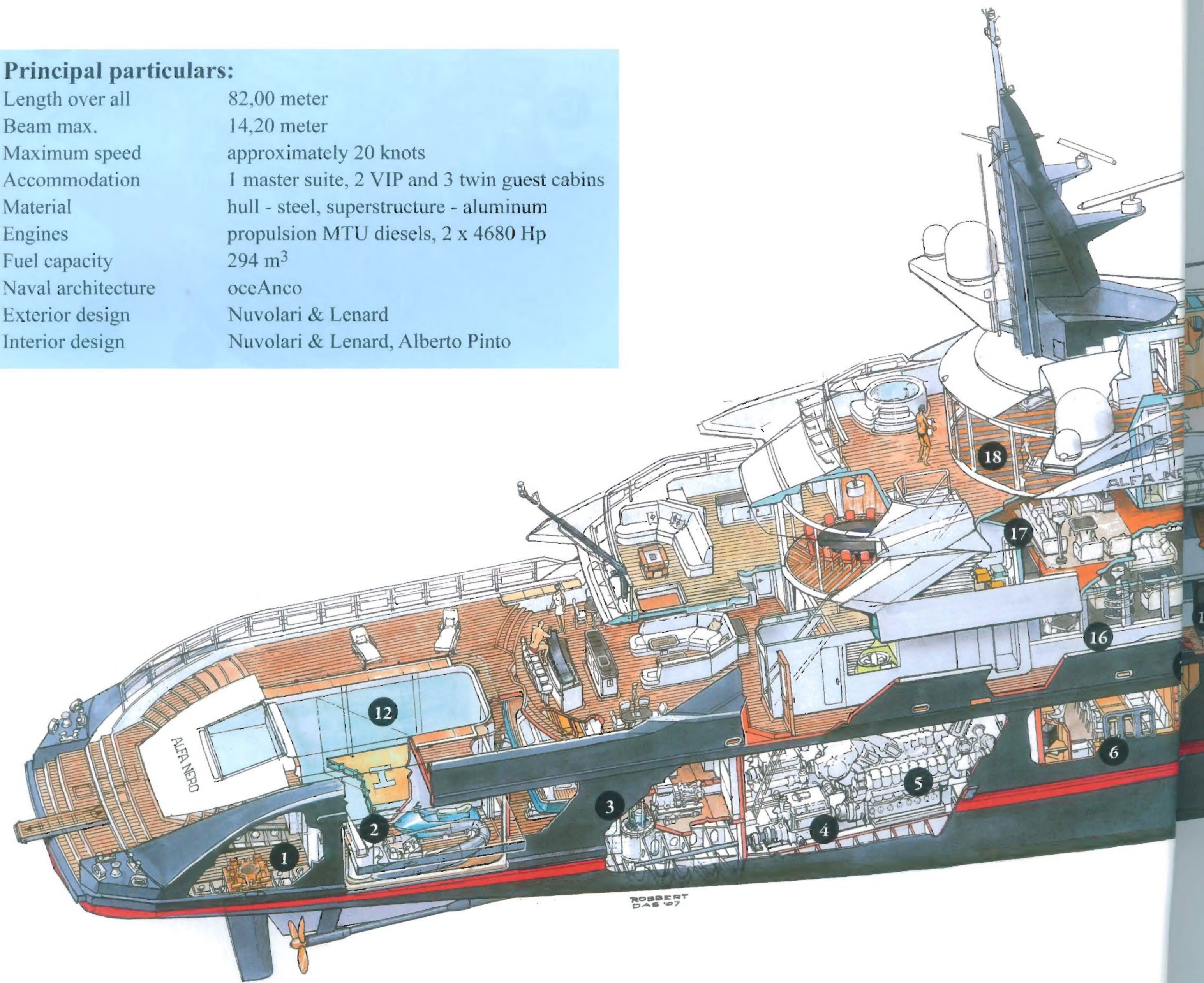
Speed

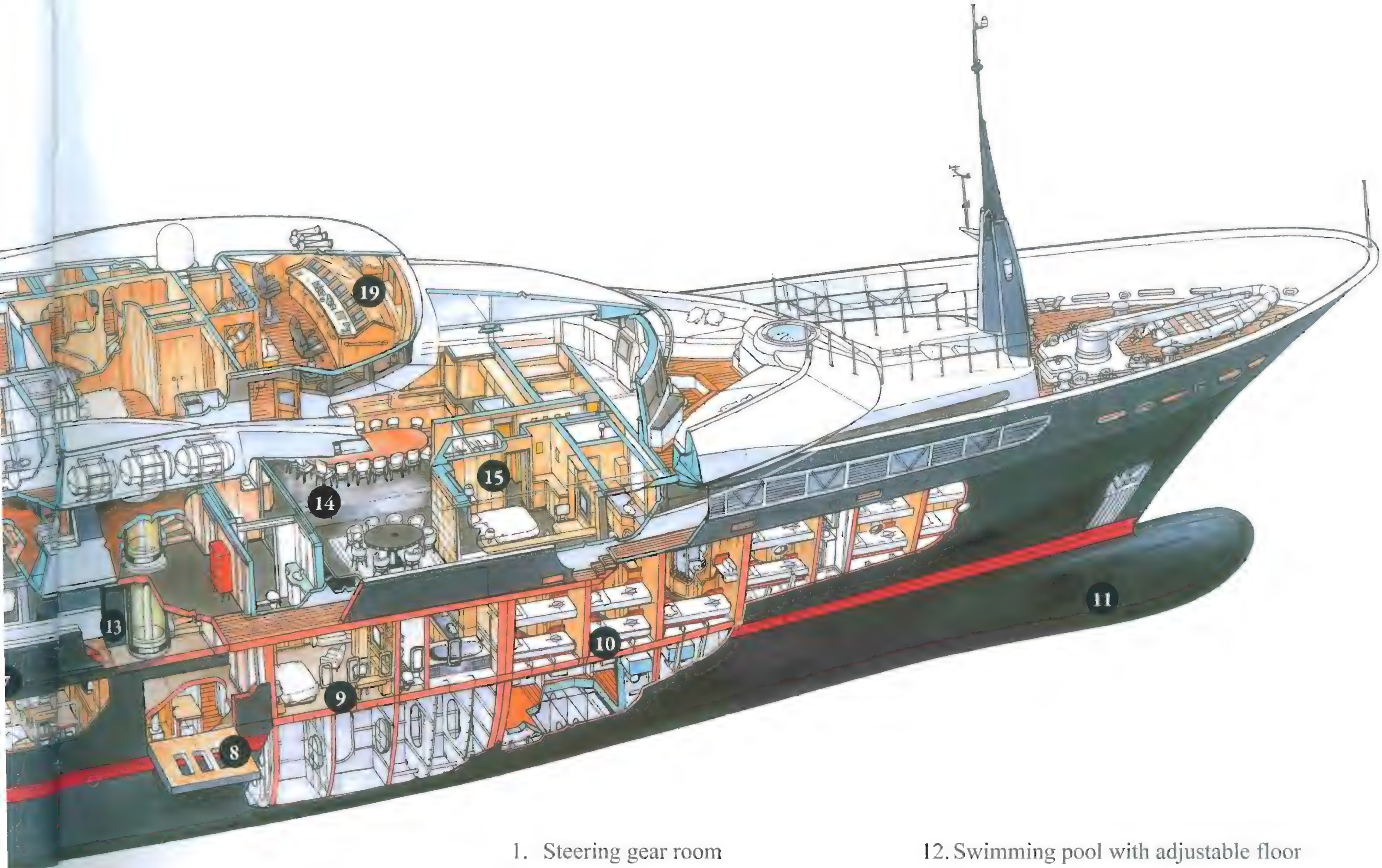
At a draft of 6.30 meter service speed will be 14 knots, with a shaft power of 3321 kiloWatt.
(main engine = 3840 kW / 150 kW for PTO (Power Take Off) 90% MCR (Maximum Continues Rating))

3. Mega Yacht

Principal particulars:

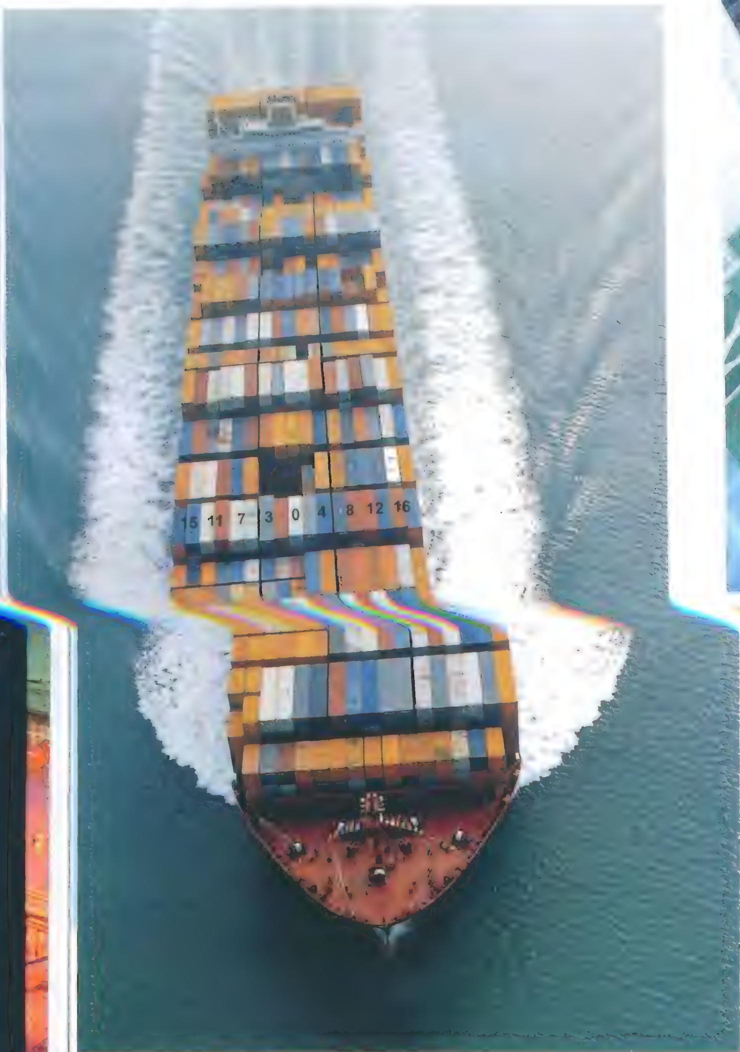
Length over all	82,00 meter
Beam max.	14,20 meter
Maximum speed	approximately 20 knots
Accommodation	1 master suite, 2 VIP and 3 twin guest cabins
Material	hull - steel, superstructure - aluminum
Engines	propulsion MTU diesels, 2 x 4680 Hp
Fuel capacity	294 m^3
Naval architecture	oceAnco
Exterior design	Nuvolari & Lenard
Interior design	Nuvolari & Lenard, Alberto Pinto





1. Steering gear room
2. Garage with toys
3. Retractable azimuth thruster
4. Reversing gearbox
5. Propulsion engine, starboard
6. Crews lounge
7. Crews mess room
8. Main lobby with guest' sea-terrace
9. VIP cabin
10. Crew cabin
11. Bow thruster
12. Swimming pool with adjustable floor In top position usable as helipad or dance floor
13. Glass elevator
14. Dining room
15. Guest cabin
16. Main Saloon
17. Upper deck saloon
18. Gym massage
19. Bridge

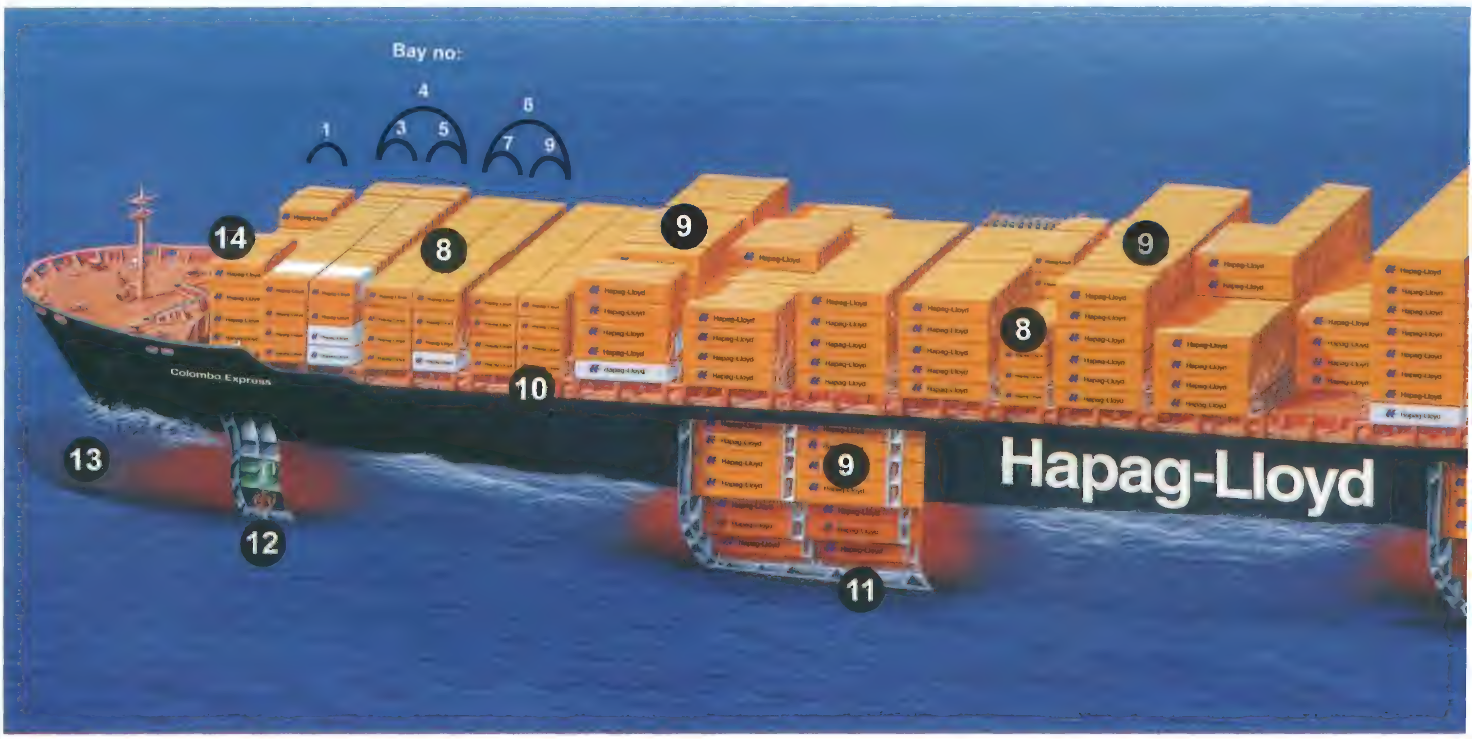
3a Container ship



The numbers shown in this picture at Bay no. 16 are row numbers

container the Tier numbers are: 82 - 90

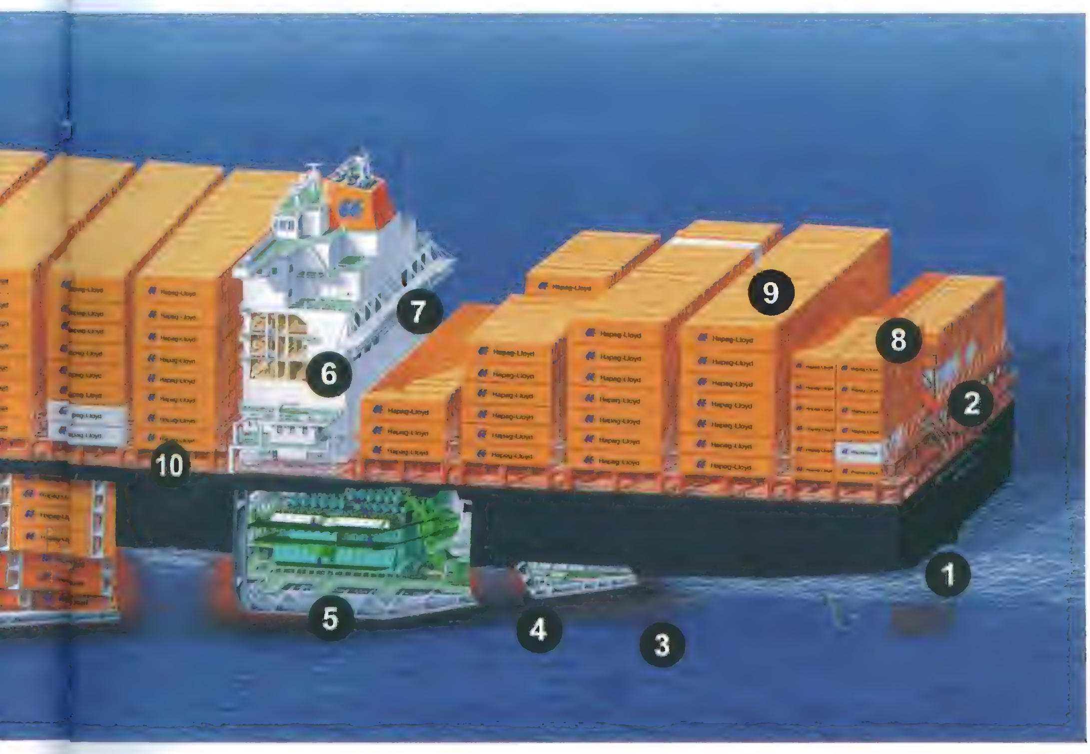
Principal particulars:	
Length over all	335 meters
Width over all	42.80 meters
Height up to 1st deck	24.50 meters
Max. draft	14.60 meters
Capacity	104,400 tons
Container capacity	8,750 TEU
Class	Germanischer Lloyd
Speed	25 knots
Main engine	MAN B&W 12k98MC, 68,640 kW
Shipyard	Hyundai Heavy Industries, S Korea



3b Multi-purpose ship

BUILDERS: JING JIANG SHIPYARD
TYPE: Highest Ice Class (up to 8.3m draft)
Double Hull Box-shaped Multi
Purpose Tweendeck/Container Carrier
FLAG: Cyprus
PORT OF REGISTRY: Limassol
CLASSIFICATION: GL + 100 A5, E3, G, General Cargo strengthened for heavy cargoes, equipped for carriage of containers, + MC E3 AUT. SOLAS II-2 Reg.54 Dangerous goods
St Lawrence / Great Lakes fitted

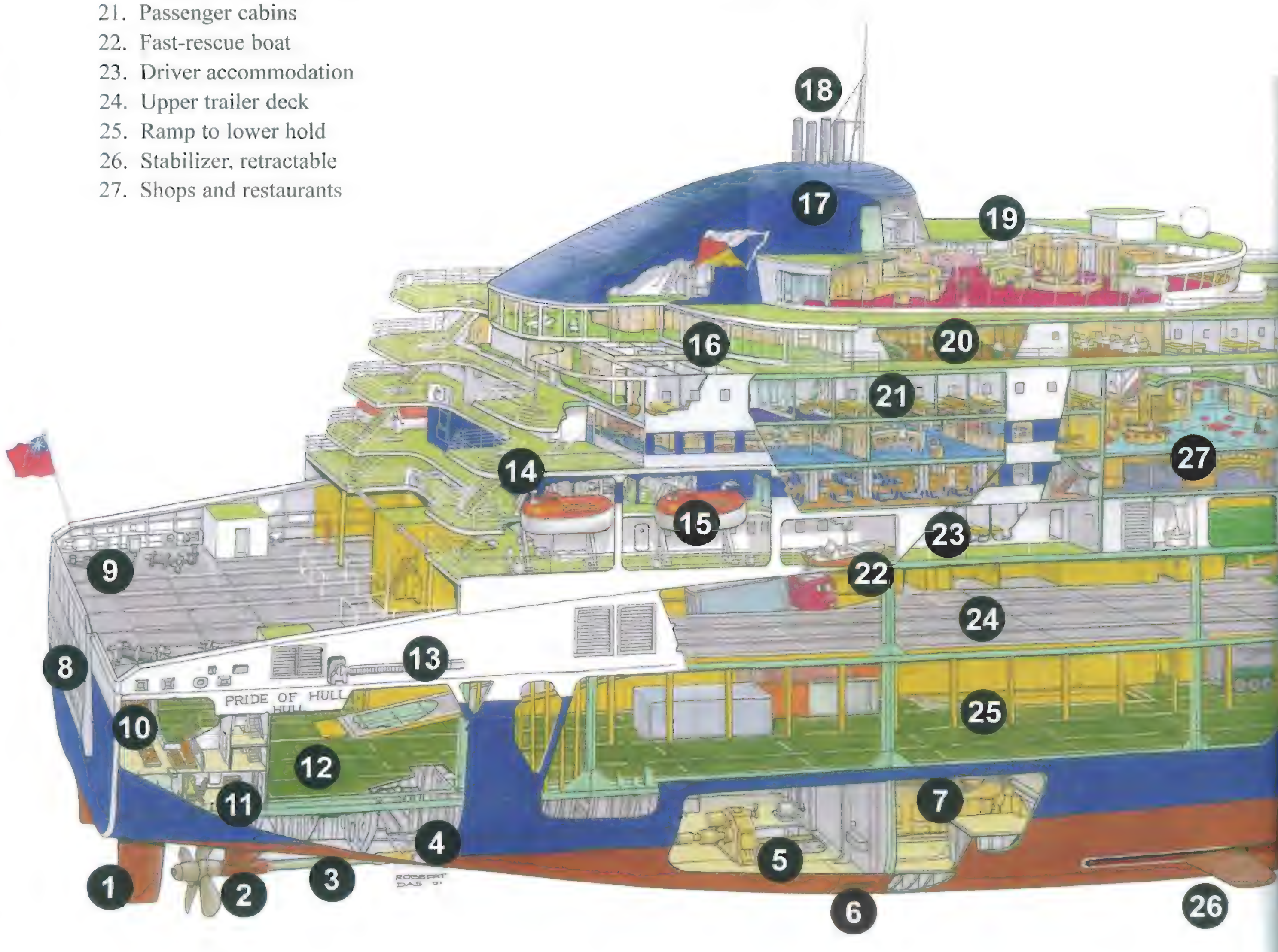
DIMENSION AND MAIN DATA
Length o. a.: 143.15M
Length b.p.: 133.00M
Breadth molded: 22.80M
Breadth max.: 23.13M
Depth to main deck: 13.30M
Deadweight summer: 17,451.7 mt
Allowance fresh water: 206 mm
Draft design / max: 8.3 m / 9.71 m
Speed at designed draft (8.3 m): abt 15.5 kn
Speed at max draft (9.71 m): abt 15.0 kn
GT: 12,993
NT: 5,894



1. Transom
2. Freefall lifeboat
3. Rudder + propeller
4. Double side hull with fuel or ballast water
5. Main engine
6. Accommodation
7. Stores crane
8. 20' containers
9. 40' containers
10. Walkway with container supports
11. Double bottom with fuel or ballast water
12. Bow thruster room
13. Bulbous bow
14. Bay 1

4 Car & Passenger Ferry

1. Rudder
2. Controllable pitch propeller
3. Stern tube
4. Ballast tank
5. Aft engine room with gearbox
6. Seawater inlet chest
7. Forward engine room with 1 of the 4 main engines
8. Stern ramp
9. Mooring gear
10. CO_2 - battery space
11. Harbor control room for loading officer
12. Main deck for trailers and double stacked containers
13. Accommodation ladder
14. Outside decks
15. Lifeboat hanging in davits
16. Deck 11
17. Funnel
18. Exhaust pipes
19. Panorama lounge
20. Officer and crew mess
21. Passenger cabins
22. Fast-rescue boat
23. Driver accommodation
24. Upper trailer deck
25. Ramp to lower hold
26. Stabilizer, retractable
27. Shops and restaurants
28. Helicopter deck
29. Entertainment spaces and bars
30. Fan room
31. Heeling tank
32. Void
33. Ro-Ro cargo
34. Web frame
35. Car deck
36. Marine evacuation system
37. Cinema
38. Satellite dome for internet
39. Satellite dome for communication (Inmarsat)
40. Radar mast
41. Officer cabins
42. Wheelhouse
43. Car deck fan room
44. Fore deck
45. Anchor
46. Bulbous bow
47. Bow thruster



Principal particulars:

Delivered:	Nov. 2001
Contract Price:	128 million USD

Classification:
Lloyd's Register +100A1, Roll-on Roll-off Cargo and Passenger Ship +LMC, UMS, SLM.

Dimensions:

Length o.a.	215.10 m
Length b.p.	203.70 m
Beam mld.	31.50 m
Draught design	6.05 m
Depth	9.40 m

Tonnage:

GT	59,925
NT	26,868
tDW design	8,800
tDW scantling	10,350

Passengers:

Total capacity	1360
- cabins	546

Car / Trailer Deck:

Cars	1380
Lane	3355 m.
Crew:	141

Access:
Stern ramp (l x w) 12.5x18 m

Machinery:
Main engines (4):

Output, Kw each	9450
Output, BHP ttl	51394
Rpm	500

Aux engines (2):

kW each	4050
Rpm	720

Propellers (2):

Diameter	4.9 m
Rpm	720

Bow thrusters (2):

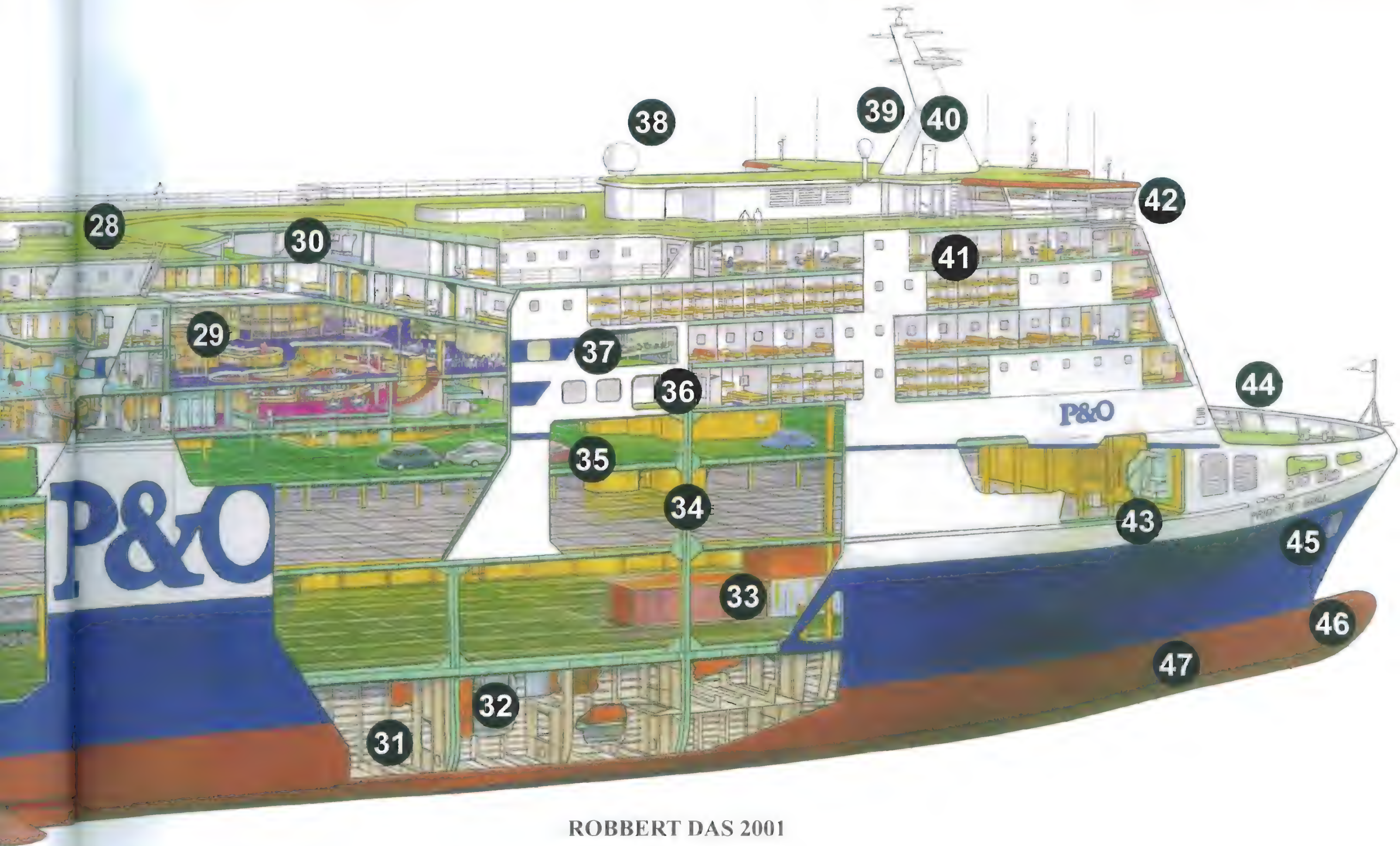
kW each	2000

Speed / Consumption:

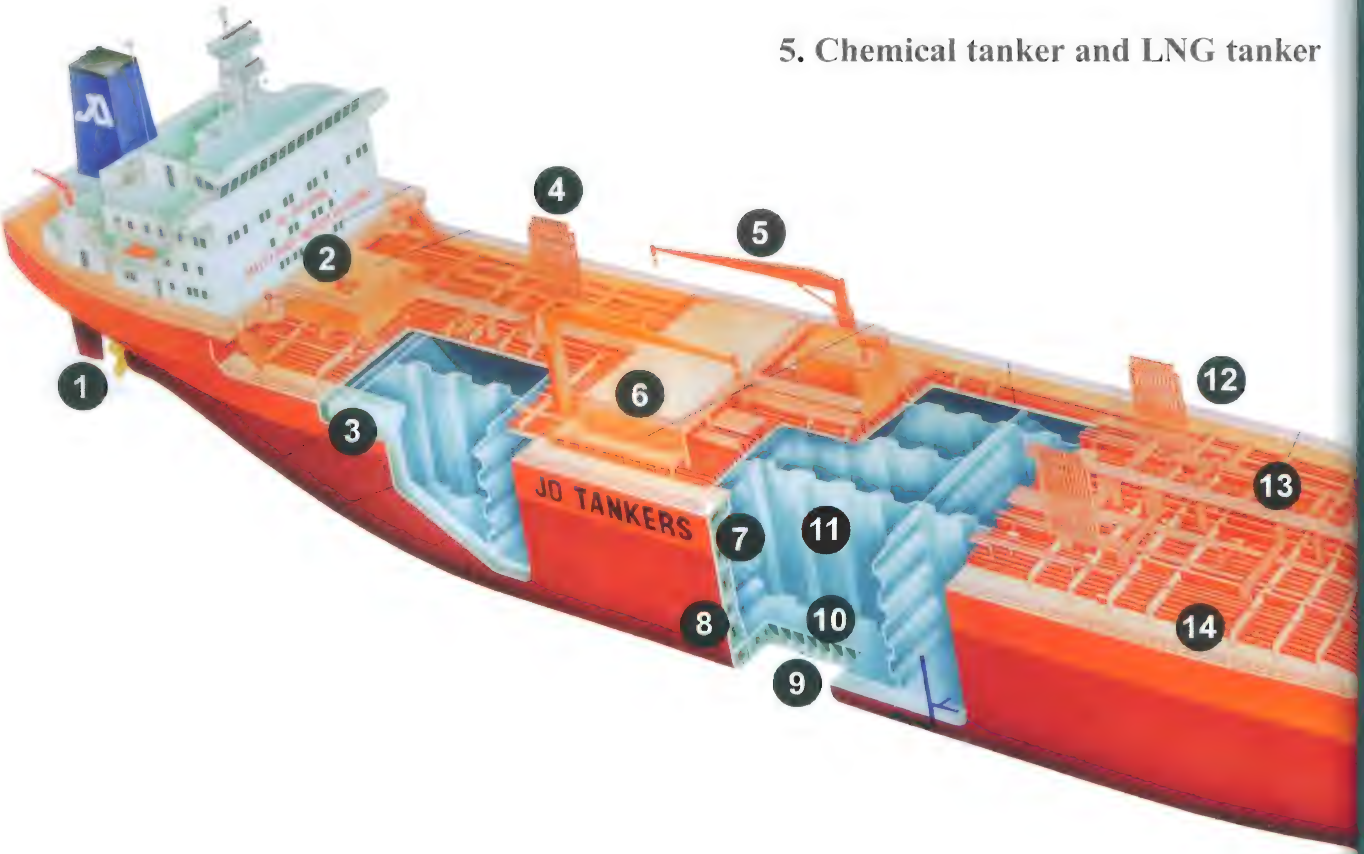
Trial speed	23.8 knots
Service speed	22.0 knots
Fuel consump.	130.8t./24hr
Fuel quality	380 cSt

Tank Capacities:

Heavy fuel oil	1000 m^3
Lub oil	50 m^3
Fresh water	400 m^3
Ballast water	3500 m^3



ROBBERT DAS 2001


JO TANKERS
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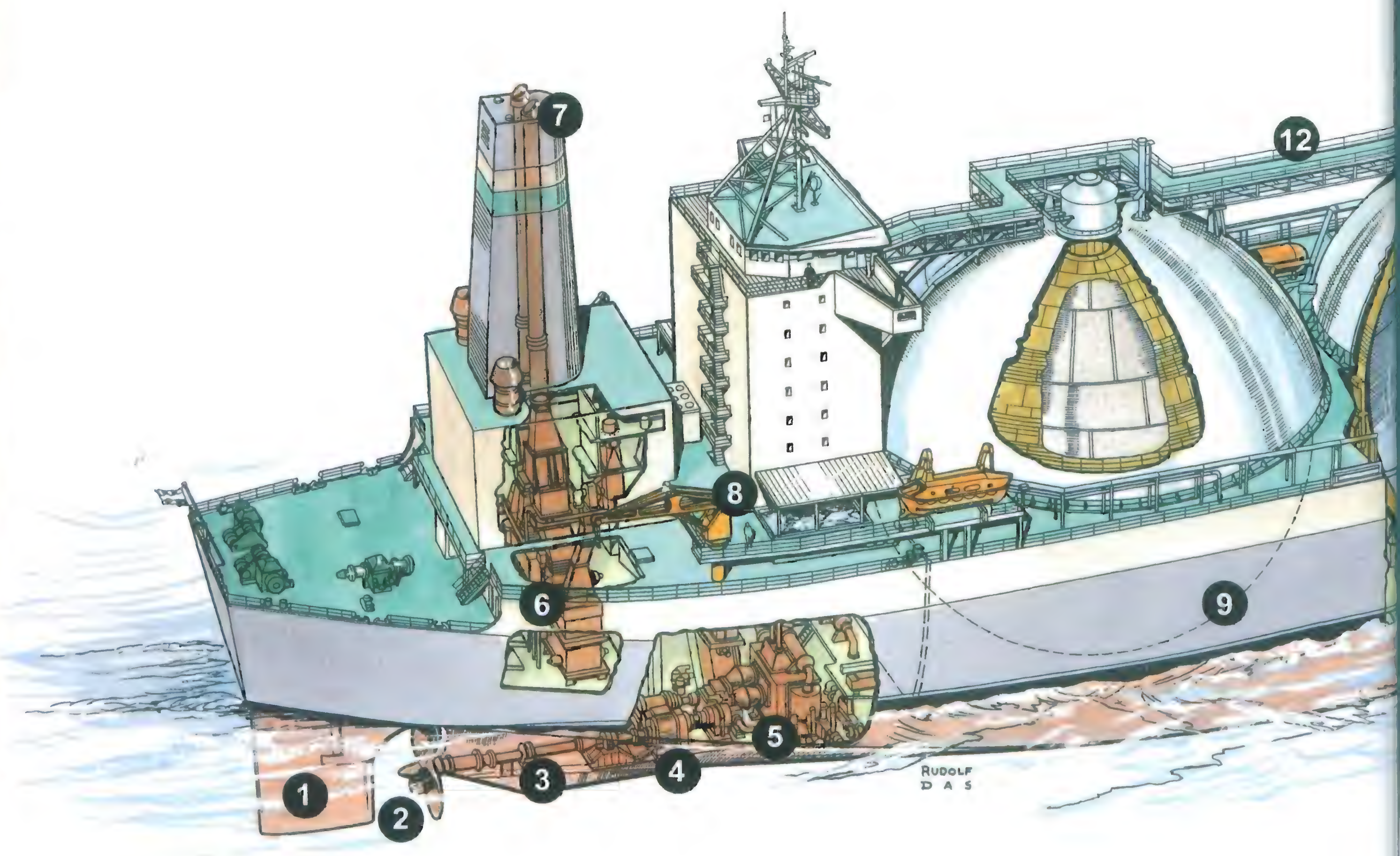
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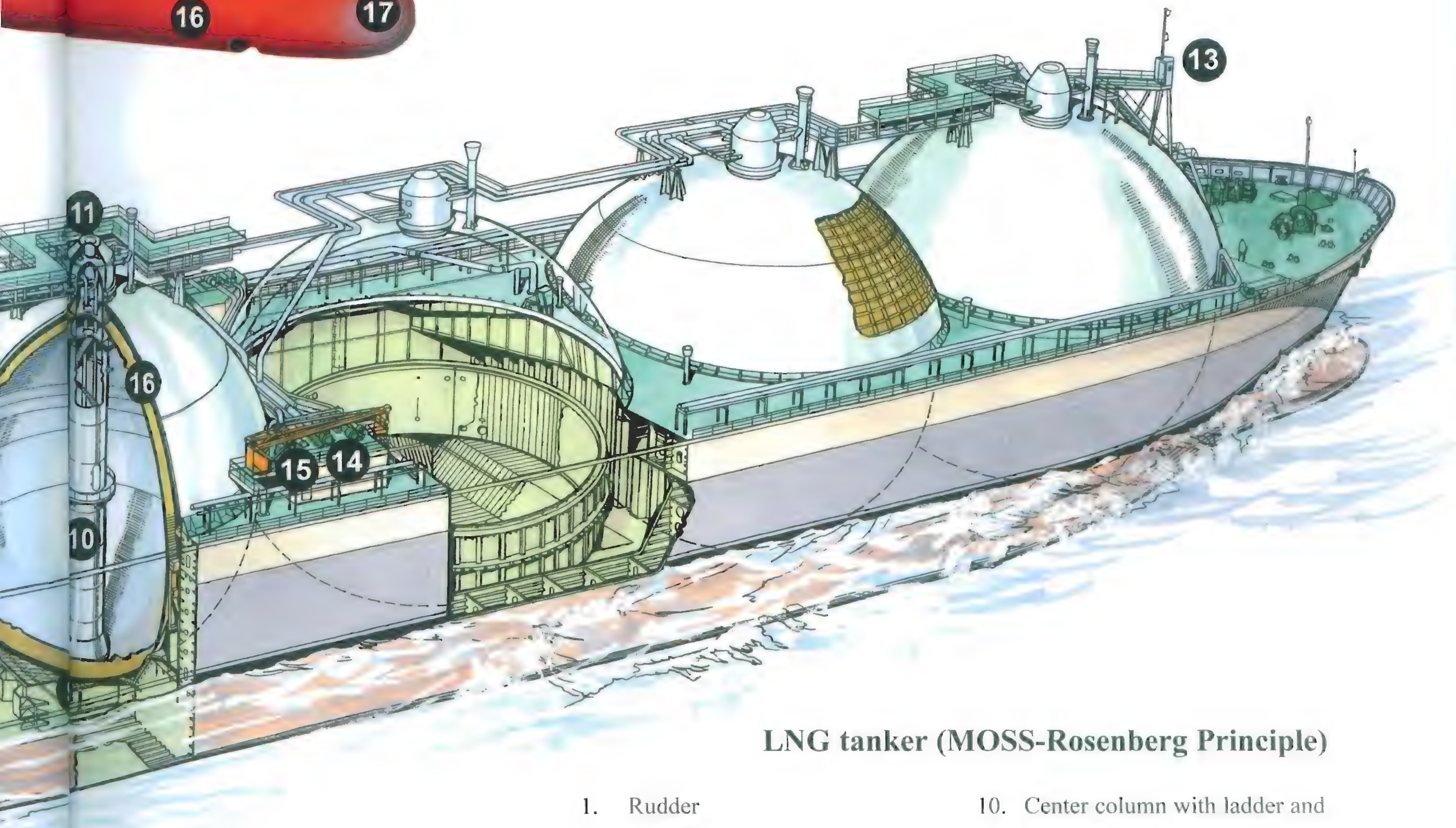
RUDOLF DAS

Chemical tanker

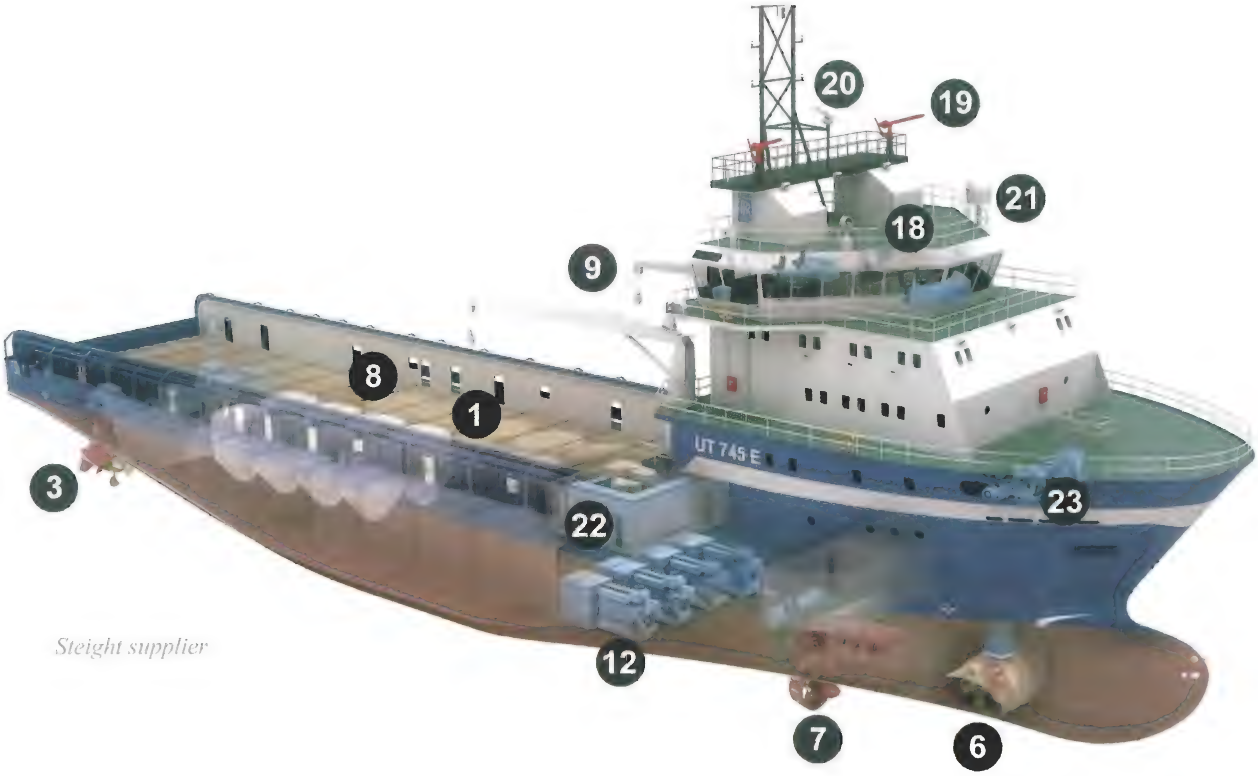
1. Rudder with conventional propeller
2. Tank heating / tank wash room
3. Coffer dam, empty space between two tanks
4. Vent pipes with pressure vacuum valves
5. Hose crane
6. Manifold
7. Transverse horizontally corrugated bulkhead
8. Wing tank in double hull
9. Double bottom tank
10. Tank top
11. Longitudinal vertically corrugated bulkhead
12. Railing
13. Catwalk
14. Deck longitudinals
15. Forecastle deck with anchor and mooring gear
16. Bow thruster
17. Bulbous bow



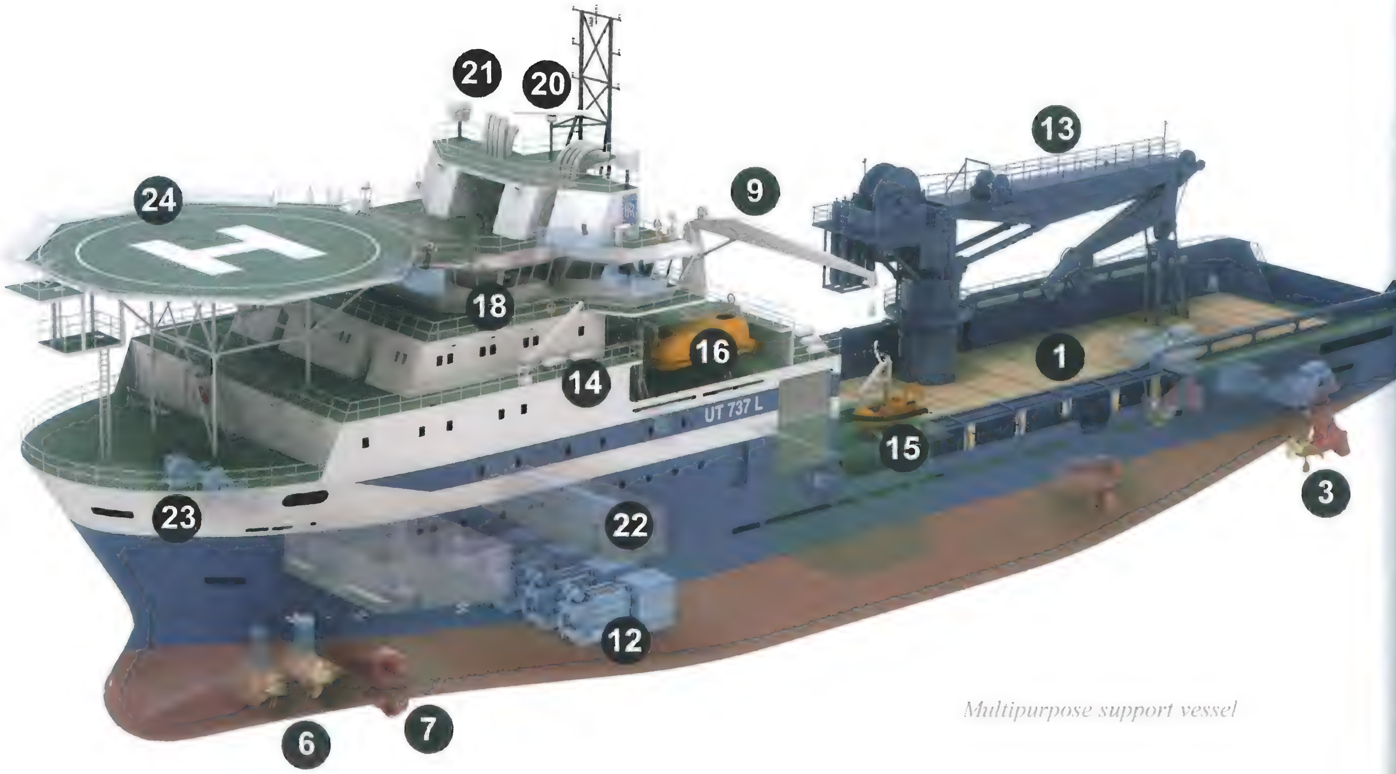
LNG tanker (MOSS-Rosenberg Principle)

1. Rudder
2. Propeller
3. Tail shaft
4. Propulsion turbines
5. Condenser
6. Boiler
7. Uptake / funnel
8. Stores crane
9. Spherical cargo tanks
10. Center column with ladder and cargo pumps
11. Cargo tank safety devices
12. Walkway
13. Forward lookout cabin
14. Manifold
15. Hose crane
16. Insulation

6 Offshore Support Vessels (OSV)



Steight supplier

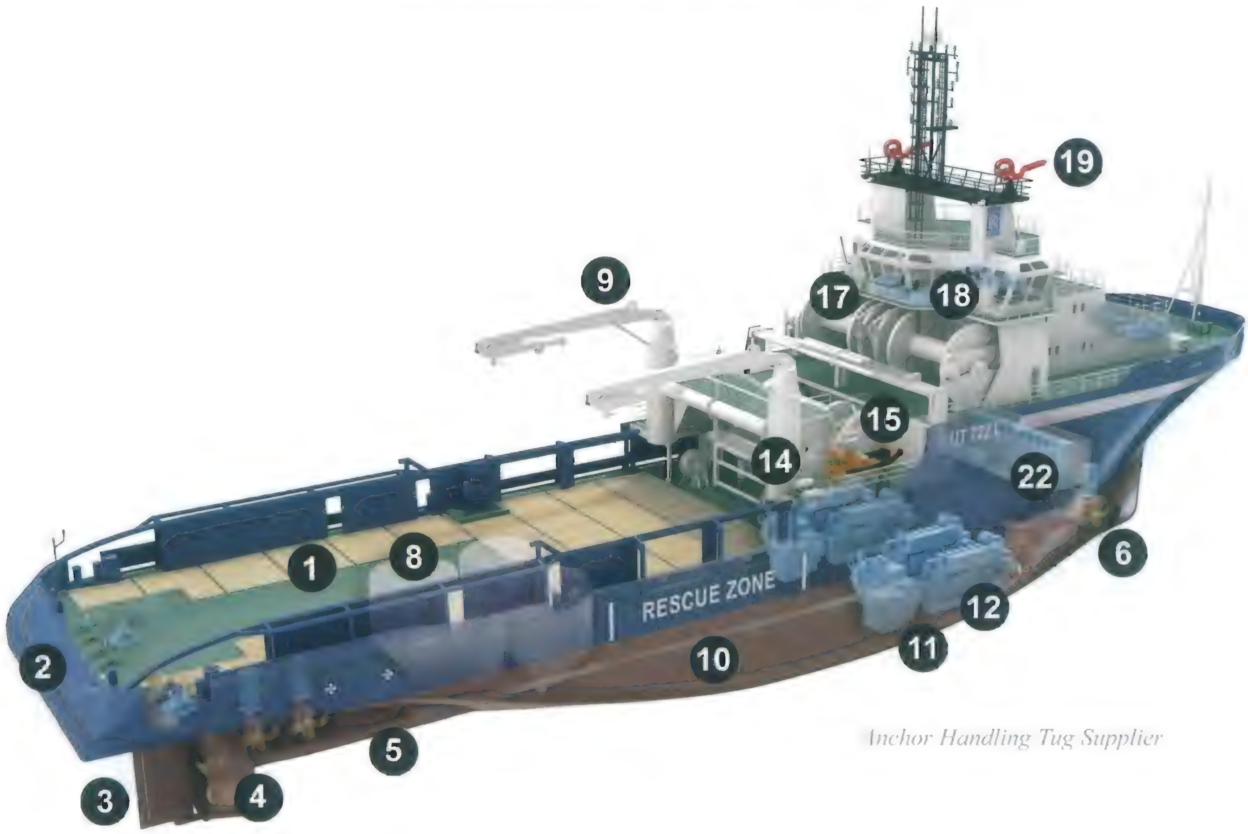


Multipurpose support vessel

1. Work deck
2. Anchor roller
3. Steering gear
4. Starboard ducted propeller
5. Stern tube
6. Transverse thruster
7. Azimuth thruster
8. Tanks for dry bulk cargo e.g. cement / mud
9. Deck cranes
10. Propeller shaft
11. (Reduction) Gear box
12. Main engine
13. Heavy lift crane
14. Life rafts
15. MOB-boat with crane
16. Life boat
17. Storage reel for steel wires for anchor handling
18. Bridge with controls for deck gear and ship's steering
19. Fire fighting monitor
20. Radar antennas
21. Antenna for communication system / satellite antenna
22. Switchboard
23. Anchor windlass
24. Helicopter deck

Multipurpose support vessel

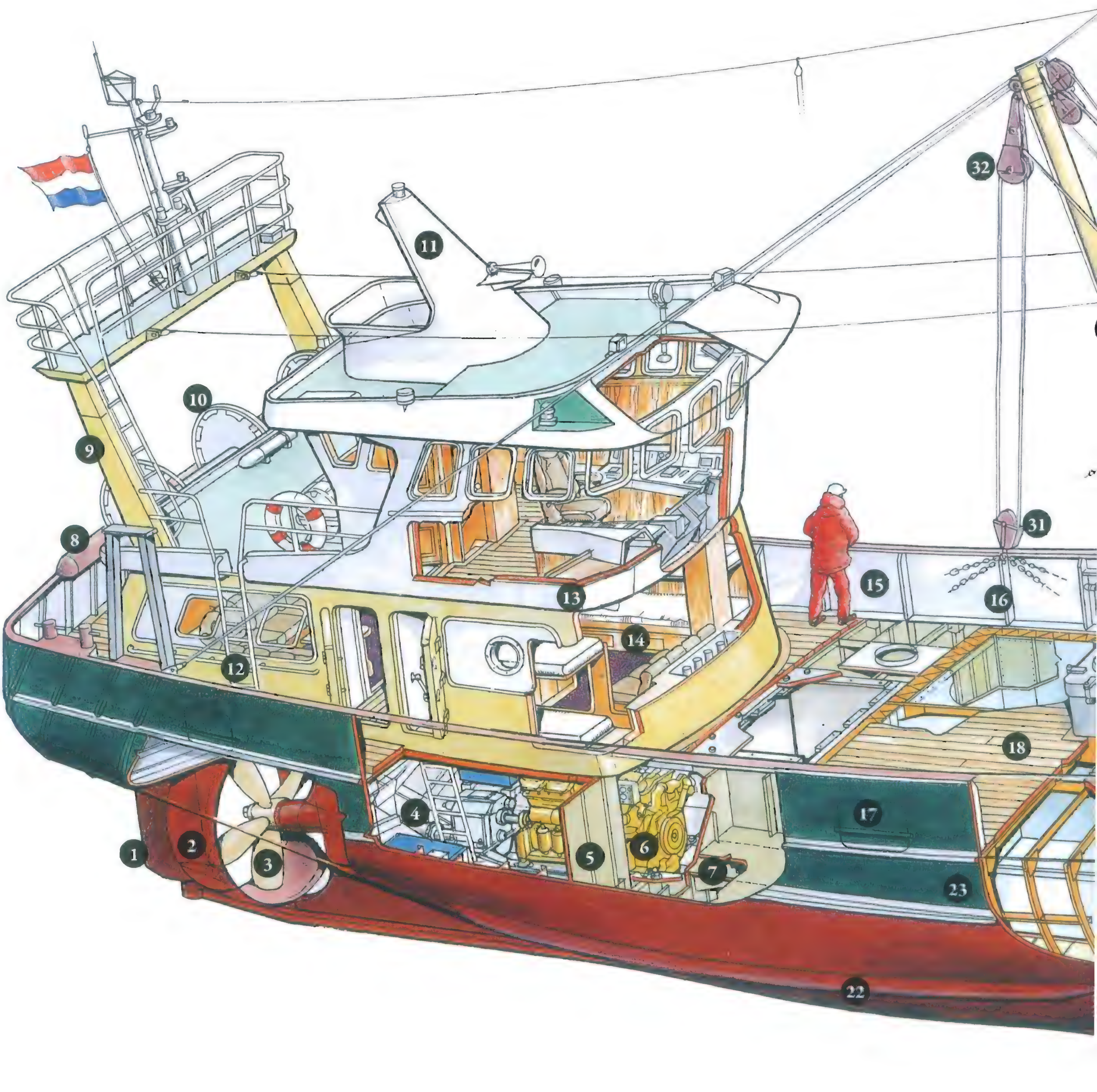
A larger type Anchor Handling Tug Supplier (AHTS)



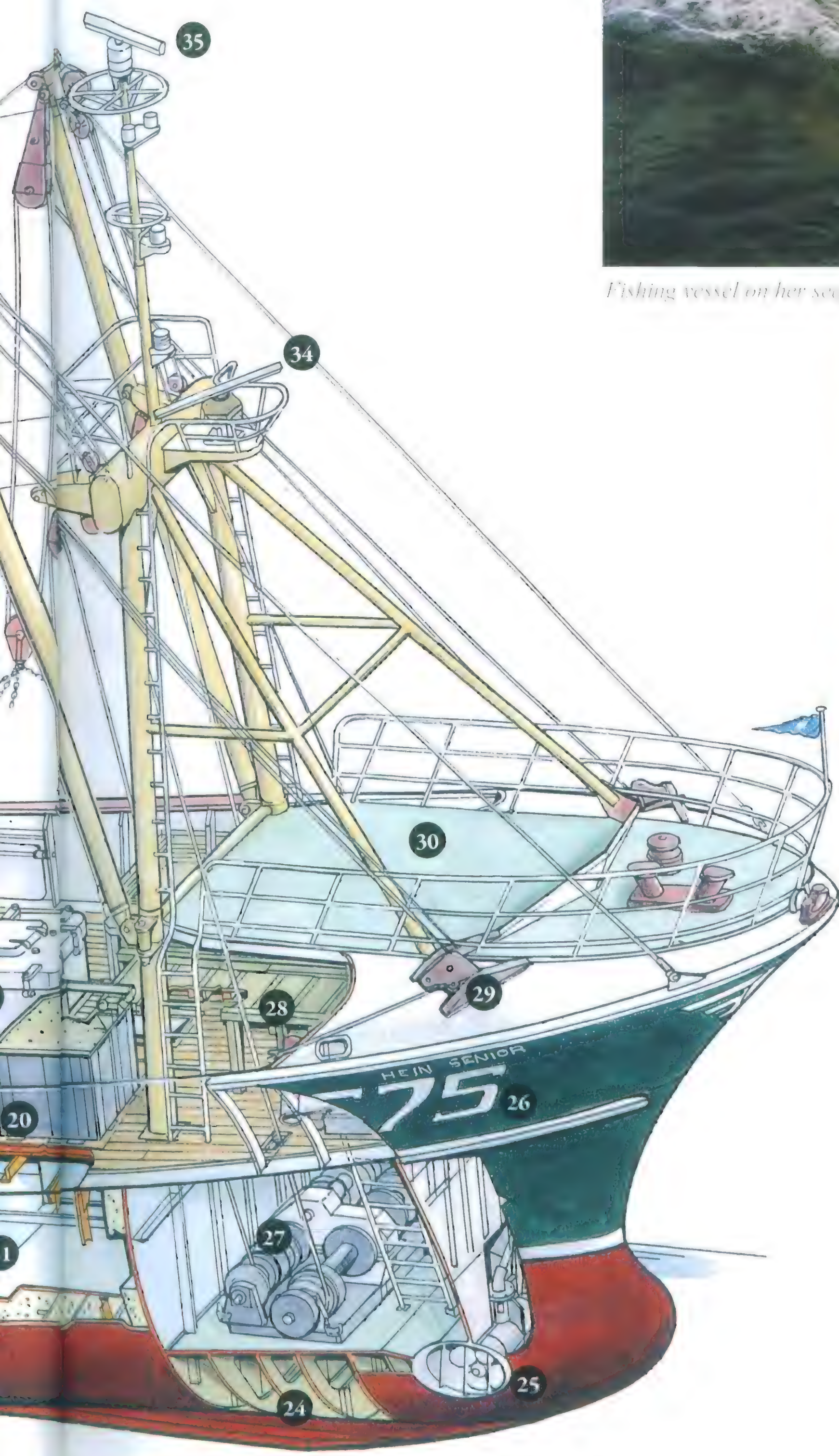
Anchor Handling Tug Supplier

7 Fishing vessel (Eurocutter)

1. Rudder
2. Kort nozzle
3. Propeller
4. Engine room
5. Engine room bulkhead
6. Main engine
7. Fuel tanks, two wing tanks and a centre tank
8. Starboard bracket pole, used when fishing is done with nets and otter boards. The derrick will not be used in that case
9. Portal mast
10. Revolving drum for nets
11. Funnel
12. Mess room, dayroom
13. Bridge with navigational equipment and control panels for main engine, drum for nets and fish winch
14. Cabin for four
15. Railing
16. Bulwark
17. Scupper hole
18. Wooden work deck
19. Hatch on fish tank
20. Drop chute
21. Fish tank, with an insulation layer of about 20 cm all around
22. Bilge keel
23. Sheer strake
24. Double bottom
25. Bow thruster installation
26. Name of the ship and fishery (registration) number



27. Fishing winch
28. Conveyor belt and fish cleaning table
29. Guide pulleys for fish line
30. Forecastle deck
31. Fishing wire blocks
32. Fishing wire
33. Fishing derrick
34. Mast
35. Radar antenna on mast



Fishing vessel on her sea trials

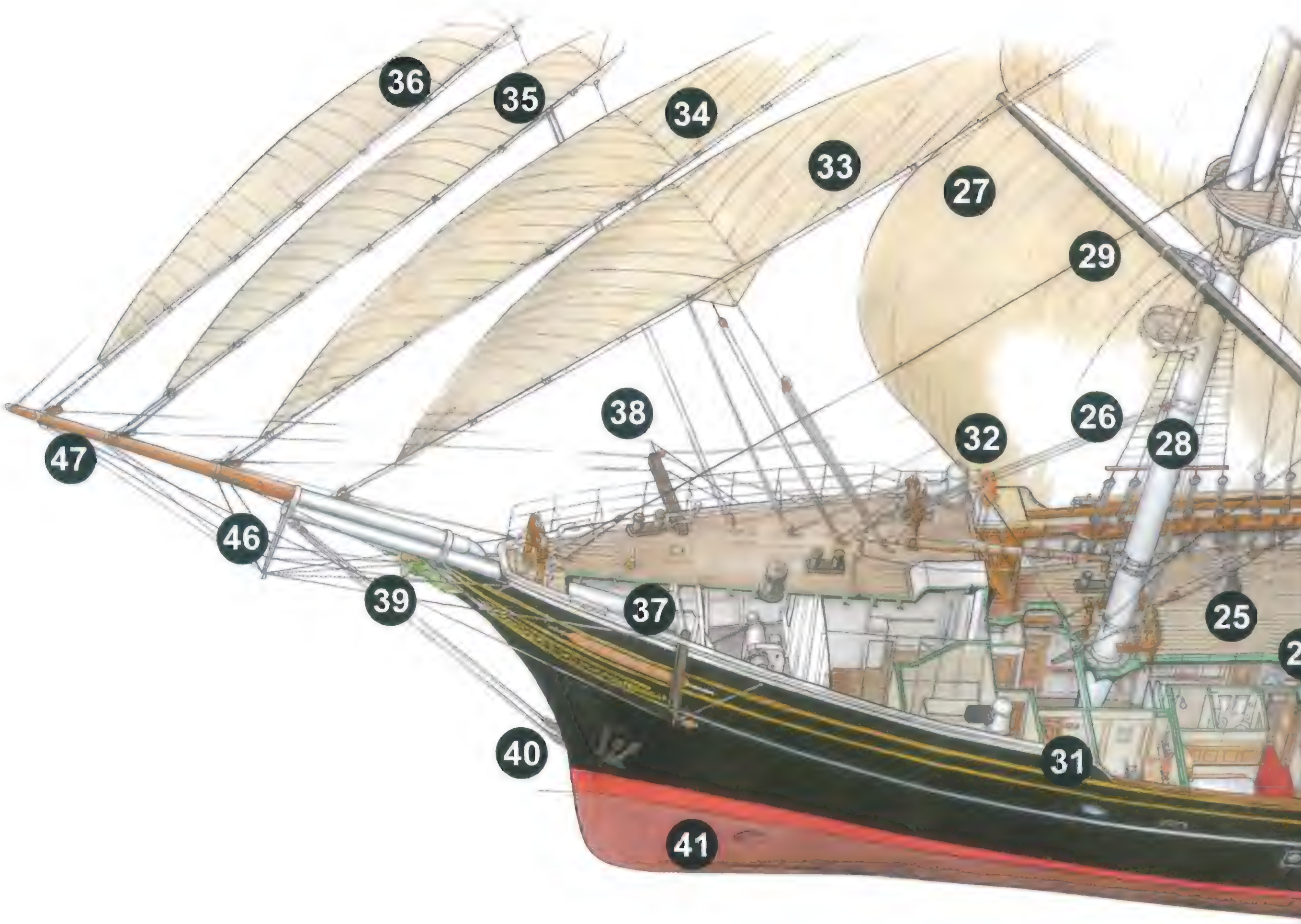
A comparable type of fishing vessel in service

Principal particulars:

Dimensions:	
Length:	23.99 meters
Breadth:	6.20 meters
Depth:	2.70 meters
Gross Tonnage:	**102 GT**
Delivered:	**2000**
Main Engine:	**300 horse power**

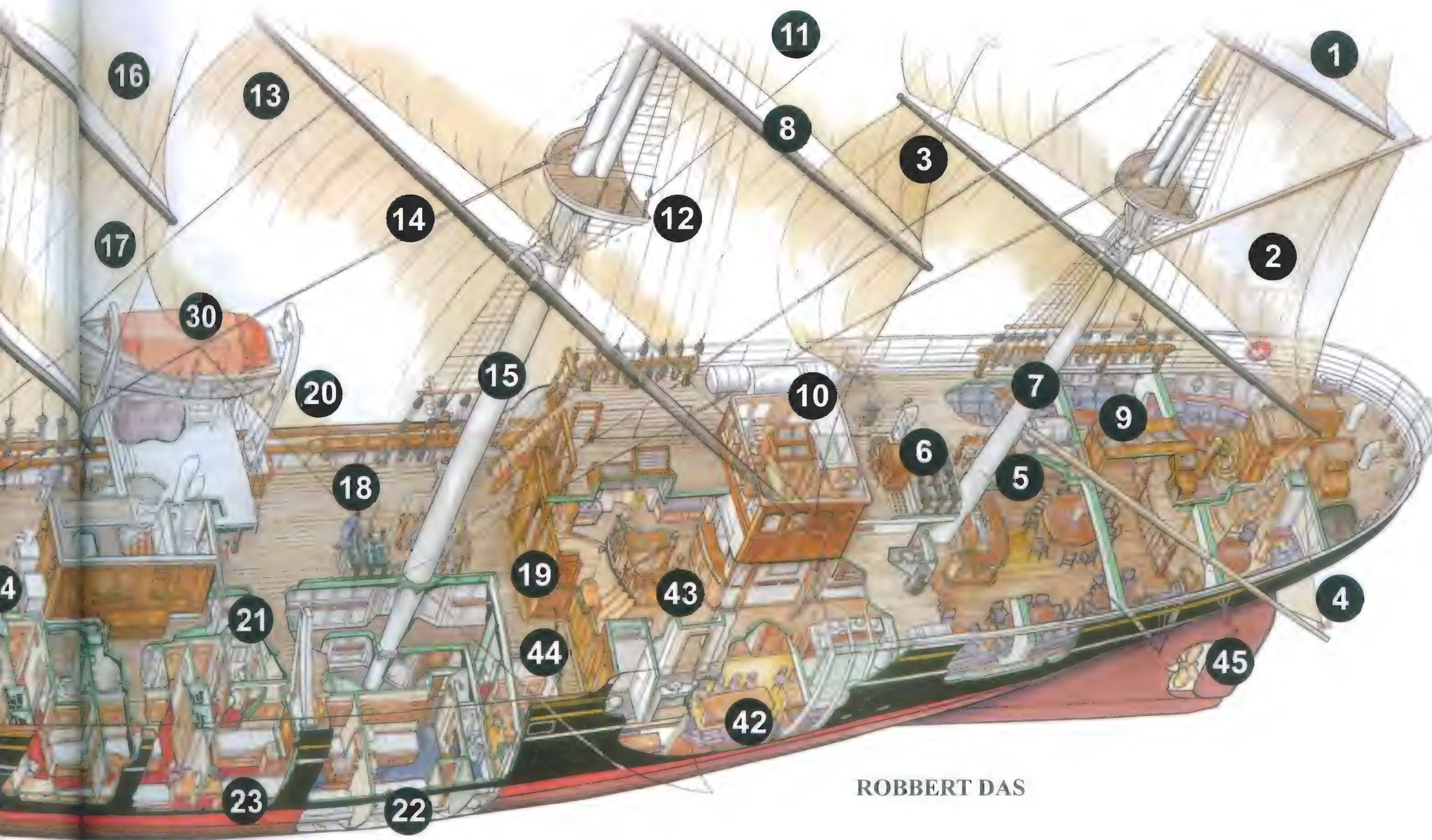
8 Clipper ship "Stad Amsterdam"

1. Mizzen topgallant
2. Mizzen topsail
3. Crossjack
4. Spanker
5. Longroom
6. Steering wheel
7. Mizzen top
8. Main lower topsail yard
9. Longroom sky light
10. Chart room
11. Main upper topsail
12. Main lower topsail
13. Main course
14. Mainstay
15. Main top
16. Fore upper topsail
17. Fore lower topsail
18. Brace winches
19. Harbor entrance
20. Davits
21. Deck pantry
22. Lower deck
23. Tween deck
24. Chicken lockers
25. Capstan
26. Boat gear
27. Fore course
28. Foretop
29. Forestay
30. Life boat
31. Crew cabins
32. Side lights
33. Fore topmast staysail
34. Inner jib
35. Outer jib
36. Flying jib
37. Bowsprit
38. Cathead
39. Figurehead
40. Bobstays
41. Bow thruster
42. Accommodation
43. Lounge
44. Owner's cabin
45. Propeller frame
46. Martingale or dolphin striker
47. Jib boom



Principle particulars:

Length over all:	76 meters
Length over deck:	60,5 meters
Beam over all:	10,5 meters
Air draft:	46,5 meters
Draft (max.):	4,8 meters
Number of sails:	29
Area of sails:	2.200 m^2
Engine:	749 kW
GT:	723
Speed under sail:	16,5 knots
Speed at engine:	11 knots
Building yard:	Damen Oranjewerf, Amsterdam
Building time:	1997 - 2000



ROBBERT DAS

CHAPTER 2

The shape of a ship

NO SMOKING
BERGSHAV

SHIP KNOWLEDGE

Covering Ship Design, Construction and Operation

QUESTIONS:

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1. Principal Dimensions

1.1 Definitions

Length over all
Length of the ship over its extremities.

Length between perpendiculars
Length from aft perpendicular (centre of rudderstock) to forward perpendicular

Load line Length
Length as used in freeboard calculation

Beam
Width of the hull, usually inside shell plating

Depth
Height from baseline to uppermost continuous deck at side, inside of plating

Draught
The maximal depth underwater, incl. shell plating.

Perpendiculars
Imaginary lines, perpendicular to the base line or plane (and the water line). On a ship there are:

- Forward Perpendicular (F_{PP} or F_P)
  This line crosses the intersection of the water line and the front of the stem.
- Aft Perpendicular (A_{PP} or A_P)
  This line usually aligns with the center line of the rudder stock (the imaginary line around which the rudder rotates).

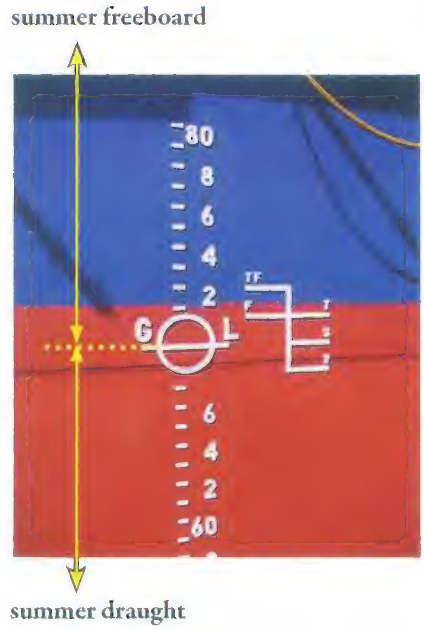
The perpendiculars are used when the lines plan is made. They are the ends of the 'block' where the underwater part of the hull fits in.

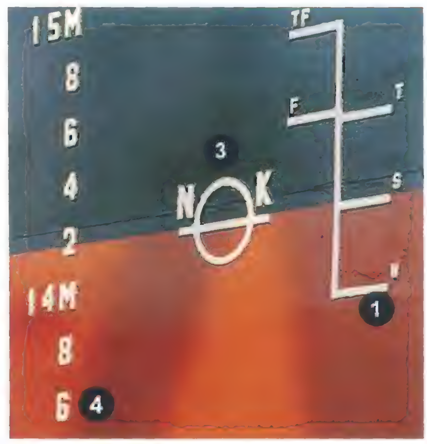
Load Line
The water line of a ship lying in the water. There are different load lines for different situations, such as:

Light water line
The water line of a ship carrying only her regular inventory.

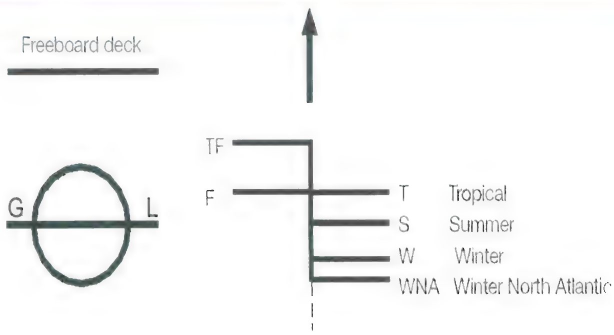
Deep water line
The water line of maximum load draught in seawater.

Construction (Scantling) water line (C_{WL})
The water line used as the limit to which the various structural components are designed.





1: Plimsoll line
2: Timber mark
3: Plimsoll mark
4: Draught marks
5: Deckline



Explanation of abbreviations used on the mark:

TF:	Tropical Fresh (for water with a density of 1.000 t/m^3)
F:	Fresh (ditto)
T:	Tropical (for water with a density of 1.025 t/m^3)
S:	Summer freeboard (ditto)
W:	Winter (ditto)
WNA :	Winter North Atlantic (ditto), only for ships, less than 100 meter
GL/NK/ LR:	Germanischer Lloyd / Nippon Kaiji Kyokai / Lloyd's Register

Deck line
Extended line from the upper side of the freeboard deck (or deck-covering) at the ship's side.

Moulded dimensions
Distance between two points, measured at inside of shell plating (or outside framing).

Base Line
Top of the flat keel plate.

Plimsoll Mark
The Plimsoll mark or Freeboard mark is a symbol indicating the maximal immersion of the ship in the water, leaving a minimal freeboard for safety. The mark consists of a circle with a diameter of one foot (one foot=0.3048m.), through which a horizontal line is drawn with its upper edge going through the centre of the circle. This level indicates the minimum freeboard in salt water summer conditions. Beside the circle is the **load line mark** consisting of a number of horizontal lines indicating the minimum freeboard as above.
All load lines are connected by a vertical line. The ship may load cargo till the upper edge of the relevant load line is at the water level.

The freeboard is marked according to the result of the freeboard calculation, where the summer freeboard in salt water is established. The main parameters in that calculation are length, width(beam), sheer, length of superstructures, length/depth ratio, etc. Allowances are made for fresh water.

The minimal freeboard depends on:
- The location on earth (latitude)
- The time of the year (summer, winter)

The Plimsoll Mark is basically to be checked by the crew. The origin lies in the safety of the people on board.

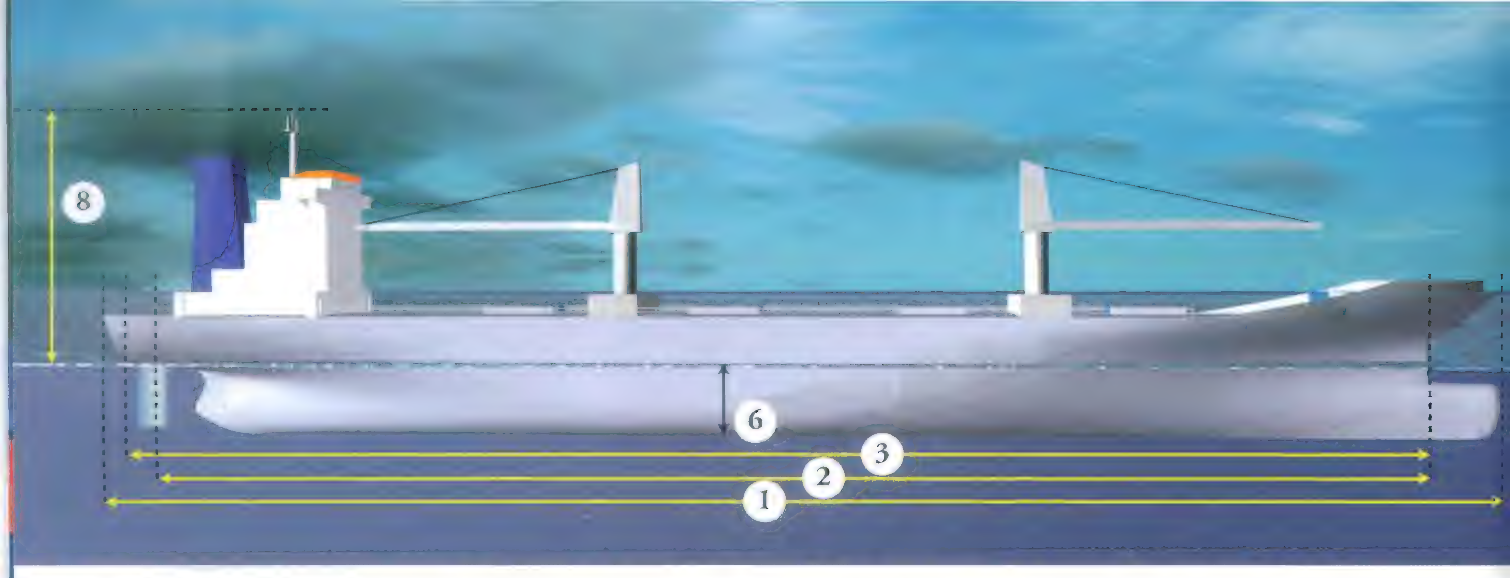
The abbreviations of the marked load lines have to be in the language of the flag state of the vessel.

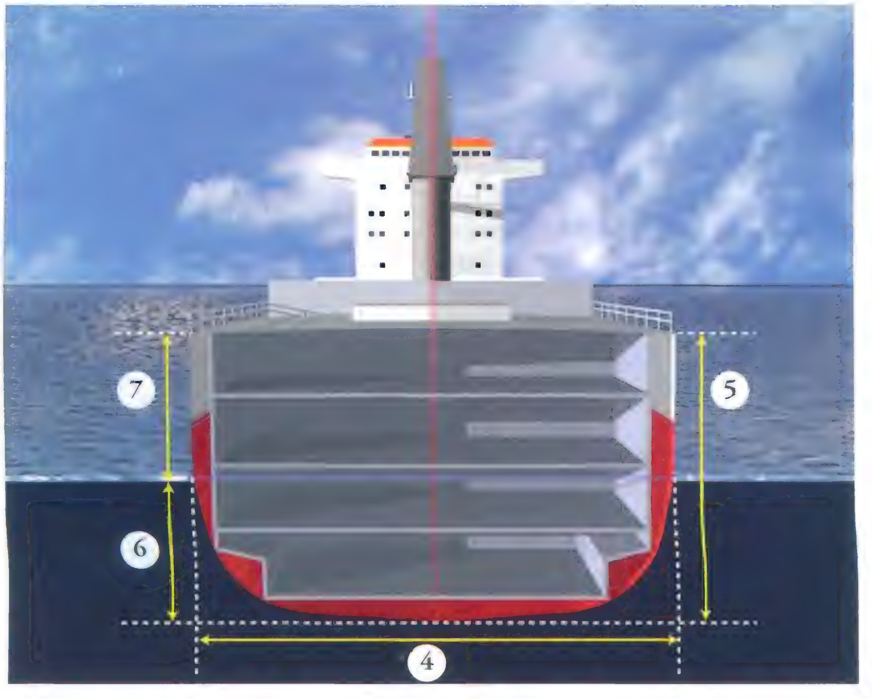
For easy checking of the position of the Mark (during the yearly load line survey), above the mark a reference line is drawn: the Deck Line. Normally at the level of the weather deck, but in case the weather deck is not the freeboard deck (e.g. RoRo, passenger ships), at the level of that deck. When the distance between the deck line and the mark is impractically large, or the connection deck shell plate is rounded off (tankers, bulkcarriers), the reference line is positioned at a lower level. The Mark and the Deck line are to be marked permanently on the port and starboardside, mid-length. (See also load-line Certificate, Chapter 6)
When a ship carries a deck cargo of timber, and certain demands are met, this ship is allowed to have more draught (less freeboard). This in connection with the additional reserve buoyancy provided by the deck cargo. To indicate this, the ship has a special Freeboard Mark for carrying a deck cargo of timber, the so-called **Timber Mark.**

Tankers carrying liquid cargoes and being completely watertight, also have allowance for less freeboard compared with other cargo ships with the same length.

The lines plan shows the shape of the ship. However, at the outside of the frames and other internals the shell plating is laid around the internals. The thickness of the shell plating is not taken into consideration for certain measurements. Those measurements are called 'moulded'

The draught marks, load line mark, Plimsoll mark and deckline have to be marked permanently on the shell plating. Usually this means that they are outlined on the plating by bead welding or by welded plate.





1. Length over all (L_{oa})
2. Length between the for and aft perpendicular ($L_{||}$)
3. Length on the water line
4. Breadth over all
5. Depth
6. Draught
7. Freeboard
8. Air draught

Breadth or beam (B_{mld})
The greatest moulded breadth, measured from side to side at the outside of the frames, but inside the shell plating.

Breadth over all
The maximum breadth of the ship as measured from the outer hull on starboard to the outer hull on port side, including rubbing bars, permanent fenders etc.

1.2 Dimensions

Length between perpendiculars (L_{pp})
Distance between the Fore and the Aft Perpendicular.

Length over all (L_{oa})
The horizontal distance over the extremities, from stem to stern.

Length on the water line (L_{wl})
Horizontal distance between the points where bow and stern are going through the water plane, at summer mark, less the shell plating, i.e. moulded.

Draught Forward (T_{fwd})
Vertical distance between the water line and the underside of the keel, as measured at the forward perpendicular.

Draught at the stern (T_a)
The vertical distance between the water line and the underside of the keel as measured at the aft perpendicular.

Trim
The difference between the draught at the stem and the draught at the stern.
Down and trimmed by the head.
Vessel, loaded with cargo, to the mark, and the draught forward is larger than at the stern.
Down and trimmed by the stern.
Vessel loaded with cargo, to the mark, and the draught aft is larger, than forward.

On an even keel, in proper trim.
The draught of the stern equals the draught of the stem.

Depth
The vertical distance between the base line and the upper continuous deck. The depth is measured at half Lpp at the side of the ship.

Freeboard
The distance between the water line and the top of the deck at the side (at the deck line). The term Summer Freeboard means the distance from the top of the Summer Load Line or the Plimsoll Mark and the upper edge of the deck line.

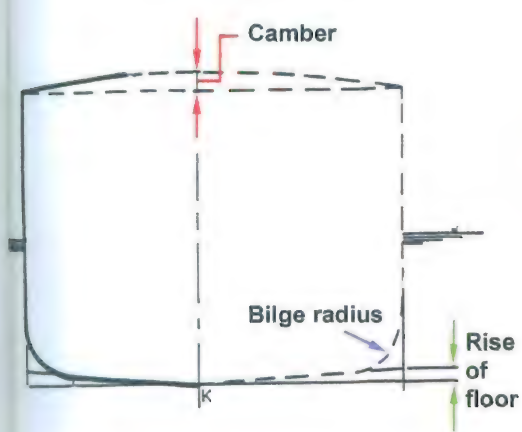
Air draught
The vertical distance between the water line and the highest point of the ship. The air draught is measured from the summer mark. If the ship has less draught one can ballast until it reaches the summer draught and so obtain its minimum air draught.

The sheer line is good visible

Sheer
This is the upward rise of a ship's deck from mid length towards the bow and stern. The sheer gives the vessel extra **reserve buoyancy** at the stem and the stern.

Camber
The transverse curvature of the weather deck. The curvature helps to ensure sufficient drainage of any water on deck.

Rise of floor
Common to some types of vessels like tugboats and fishing boats. This is the upward deviation from the baseline of the lower edges of the floors from the keel towards the bilges, in order to collect water inside the hull near center line, for easy pumping. This was used in all ships but out of fashion in large ships to-day. They have flat bottoms.



Bilge radius
Gives the bilge radius of the ship.

1.3 Proportions

The ratios of some of the dimensions discussed above can be used to obtain information on resistance, stability and manoeuvrability of the ship. Some widely used ratios are:

L/B
The ratio of length and breadth: L/B can differ quite significantly depending on the type of vessel. Common values:

Passenger ships	6-8
Freighters	5-7
Tug boats	3-5

A larger L/B value is favourable for speed, but unfavourable for manoeuvrability and stability.

L/D
The length/depth-ratio. The customary values for L/D vary between 10 and 15. This relation plays a role in the determination of the freeboard and the longitudinal strength.

B/T (T = Draught)
The breadth/draught-ratio, varies between 2 and 4.5. A larger breadth in relation to the draught (a larger B/T-value) gives a greater initial stability.

B/D
The breadth/depth-ratio, varies between 1 and 2. If this value increases, it will have an unfavourable effect on the stability (because the deck edge will be submerged when the vessel heels) and strength.

An example of a ship with a small depth

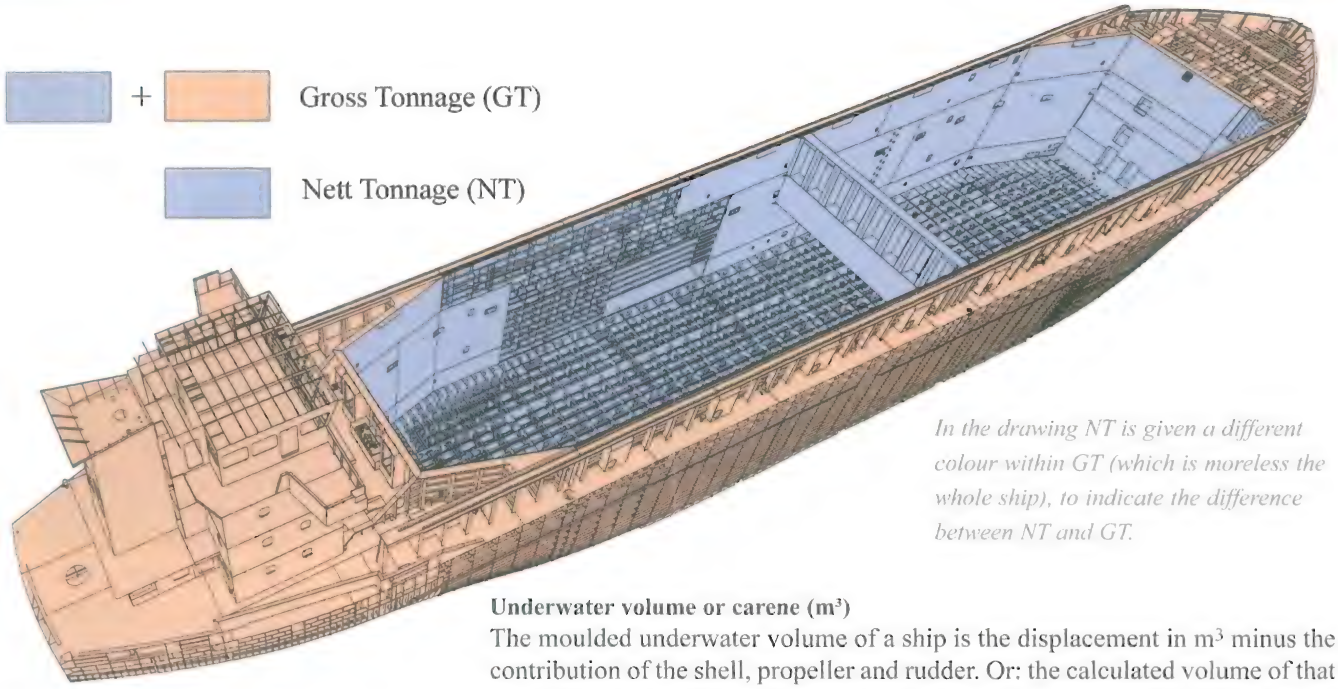
1.4 Volumes and weights

General
The size of a ship can be expressed by using terms which describe the characteristics of the ship. Each term has a specific abbreviation. The type of ship determines the term to be used. For instance, the size of a container vessel is expressed in the number of 20' containers it can load; a Ro-Ro carrier's size is given by the total lane metres and a passenger ship in the number of passengers it can carry.

Measurement Treaty
All aspects concerning the measurements of seagoing vessels are arranged in the Certificate of Registry Act of 1982. Part of the Certificate of Registry Act is the International treaty on the measurement of ships, as set up by the IMO-conference in 1969. The treaty applies to seagoing vessels on international voyages with a minimum length of 24 metres and came into force in July 1994.

At the IMO-conference in 1969 the new measurements for the "Gross Tonnage" and "Nett Tonnage" were introduced, to establish a world-wide standard in calculating the size of a ship. In many countries the Gross Tonnage is used to calculate harbour dues and pilotage, or to determine the number of people in the crew.

Register ton.
To determine the size of a ship the **Register Ton** is used. It is based on volume where one register ton equals 100 cft, or 2.83 m^3



In the drawing NT is given a different colour within GT (which is moreless the whole ship), to indicate the difference between NT and GT.

Gross Register Tonnage

The Gross Register Tonnage (**GRT** or **GT**), usually called Gross Tonnage, is calculated using a formula that takes into account the ship's volume in cubic metres below the main deck and the enclosed spaces above the main deck.

This volume is then multiplied by a coefficient, which results in a non-dimensional number (this means no values of T or m^3 should be placed after the number). All measurements used in the calculation are moulded dimensions.

In order to minimize the daily expenses of a ship, the ship owner will keep the GT as low as possible. One way of doing this is by keeping the Depth small, so more cargo can be placed on deck. This strategy is in particular used in container-feeder ships. As a consequence, dangerous situations can occur as the loss of reserve buoyancy can result in a loss of stability and more "water on deck".

Nett Register Tonnage

The Nett Register Tonnage is also a non-dimensional number that describes the volume of the cargo space. The **NT** is derived from the GT by subtracting the volume of space occupied by:

- crew
- navigation equipment
- the propulsion equipment(partly)
- workshops
- ballast

The NT may not be less than 30% of the GT.

Underwater volume or carene (m^3)

The moulded underwater volume of a ship is the displacement in m^3 minus the contribution of the shell, propeller and rudder. Or: the calculated volume of that part of the hull which is immersed in the water, on the outside of the frames without extensions. The influence of the shell in weight, is compensated by the extra displacement.

Displacement (m^3)

The displacement is the volume of the part of the ship below the water line including the shell plating, propeller and rudder.

Displacement D or Δ (ton)

The displacement is the weight of the volume of water displaced by the ship. One could also say: the displacement equals the total mass of the ship.

Lightship weight (ton)

This is the weight of the ship including the regular inventory, but without any cargo, fuel or crew. The regular inventory includes: anchors, life-saving appliances, lubricating oil, paint, etc.

Deadweight (ton)

This is the weight a ship can load till the maximum allowable immersion (to summer load line). This is a fixed value, which is unique for each ship.

Displacement (ton) = waterdisplacement (m^3) * density of water (t/m^3)

Through the years, there is usually a build-up of mud in the ballast tanks, additional spares are taken on board, and less is going off. There is also water, which cannot be pumped out. The total weight of all this, is called the **ship-constant**, and has to be subtracted from the deadweight.

Deadweight (ton) = design displacement Δ(ton) - light ship weight (ton)
Deadweight (ton) = maximum weight Δ(ton) - actual weight Δ(ton)

Cargo Capacity (t)

This is the total weight of cargo a ship is designed to carry, at a certain time. The actual cargo loaded (in tons) is not a fixed number, it depends on the ship's maximum allowable immersion at the relevant season, which will include the capacity (in tons) of fuels, spares, provisions and drinking water.

For a long voyage a large quantity of fuels has to be taken, which reduces the cargo capacity. If, on the other hand, the ship refuels (bunkers) underway, the cargo capacity is larger upon departure. The choice for the amount of fuel on board and the location for refuelling depend on many factors, but in the end the master has final responsibility for the choices made.

Cargo capacity (tons) = deadweight (tons) - ballast, fuel, provisions (tons).

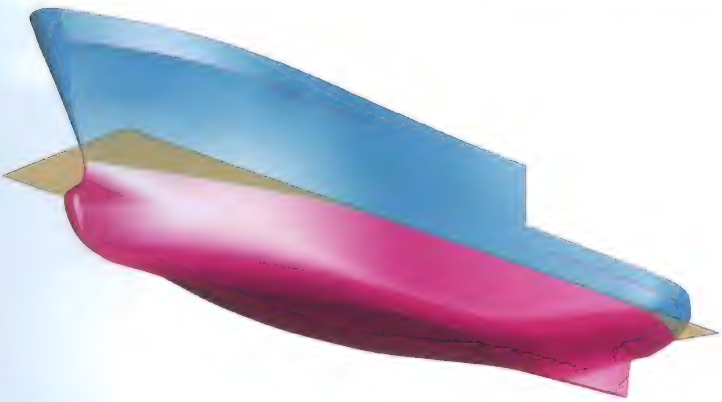
The cargo capacity largely determines the amount of money a ship generates.

2. Form coefficients

Form coefficients define the characteristics of the vessel's shape below the design waterline. This makes it possible to get an impression of the shape of the underwater body of a ship without extensive use of any data. However, the form coefficients do not contain any information on the dimensions of the ship, they are non-dimensional figures.

2.1 Water-plane coefficient. C_w (α)

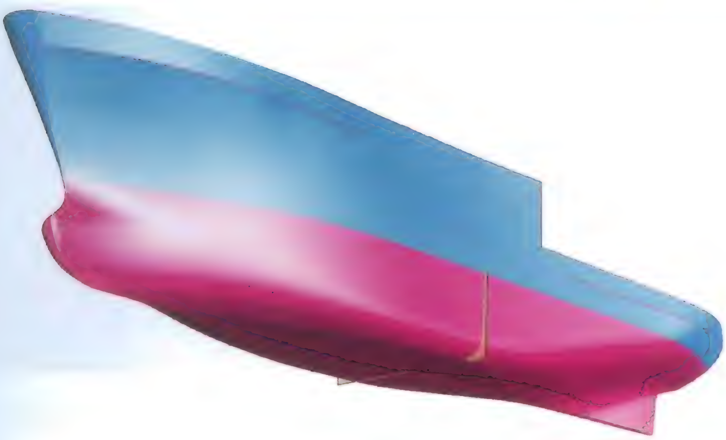
$$\text{Waterplane-coefficient } (C_w) = \frac{A_w}{L_{pp} \times B_{mld}}$$



The water-plane coefficient gives the ratio of the area of the water-plane (**A_w**) and the rectangular plane bouded by **L_{pp}** and breadth moulded (**B_{mld}**). A large waterplane coefficient in combination with a small block coefficient (or coefficient of fineness) is favourable for the stability in both transverse and longitudinal direction.

2.2 Midship Section coefficient, C_m. (β)

$$\text{Midship-coefficient } (C_m) = \frac{A_m}{B_{mld} \times T}$$



A ship with a large midship coefficient and a large block coefficient.

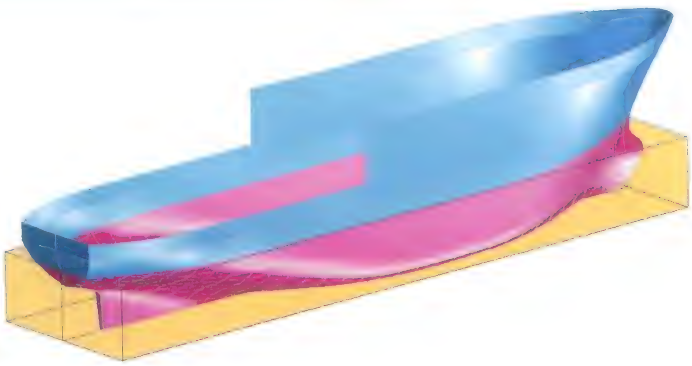
The midship coefficient gives the ratio of the area of the midship section (**A_m**) and the area bounded by B_{mld} and **T**.

2.3 Block coefficient, coefficient of fineness, C_b. (δ)

The block coefficient gives the ratio of the volume of the underwater body (V) and the rectangular block bounded by L_{pp}, Bmld and draught (T). A vessel with a small block coefficient is referred to as 'fine'. In general, fast ships have small block coefficients.
Customary values for the block coefficient of several types of vessels:

Ship type	Block coefficient C_b	Appr. ship speed
Lighter	0.90	5 – 10 knots
Bulk carrier	0.80 – 0.85	12 – 17 knots
Tanker	0.80 – 0.85	12 – 16 knots
General cargo	0.55 – 0.75	13 – 22 knots
Container ship	0.50 – 0.70	14 – 26 knots
Ferry boat	0.50 – 0.70	15 – 26 knots

$$\text{Block coefficient } (C_b) = \frac{\text{Volume}}{L_{pp} \times B_{mld} \times T}$$



Graphical representation of the block coefficient.

2.4 Prismatic coefficient, C_p. (phi)

The Prismatic Coefficient gives the ratio of the volume of the underwater body and the block formed by the area of the Midship Section (Am) and L_{pp}. The C_p is important for the resistance and hence for the necessary power of propulsion (if the C_p decreases, the necessary propulsion power also becomes smaller).

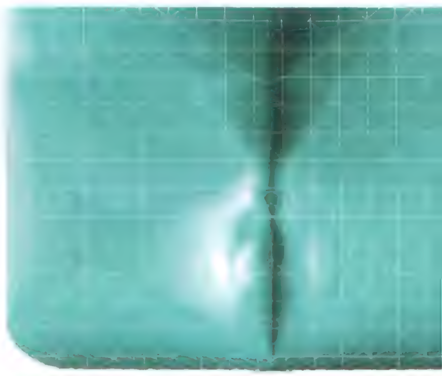
The maximum value of all these coefficients is reached in case of a rectangular block, and equals 1. The minimal value is theoretically 0.

$$\frac{V}{L_{pp} \times A} = \frac{L_{pp} \times B \times T \times C_b}{L_{pp} \times B \times T \times C_m} = \frac{C_b}{C_m}$$

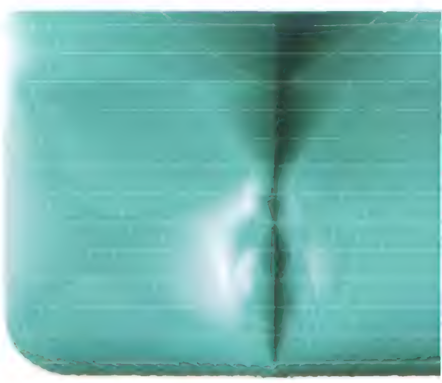
Graphical representation of the prismatic coefficient

A ship with a small block-coefficient and a large midship section coefficient

A ship with a large block-coefficient and a large midship section and prismatic coefficient



Waterlines, ordinates, verticals, diagonals



Waterlines, ordinates

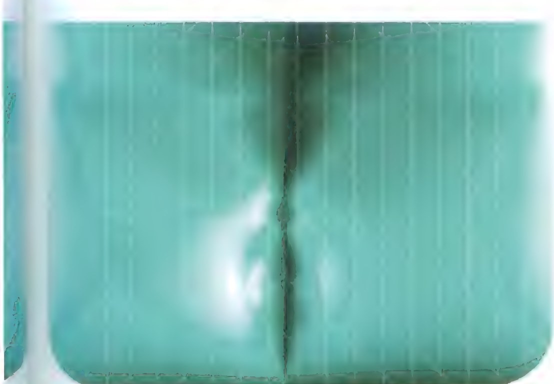
3. Hull-form (Lines plan)

When the principal dimensions, displacement and hull-form coefficients are known, one has an impressive amount of design information, but not yet a clear image of the exact geometrical shape of the ship. The shape is given by the **lines plan**.

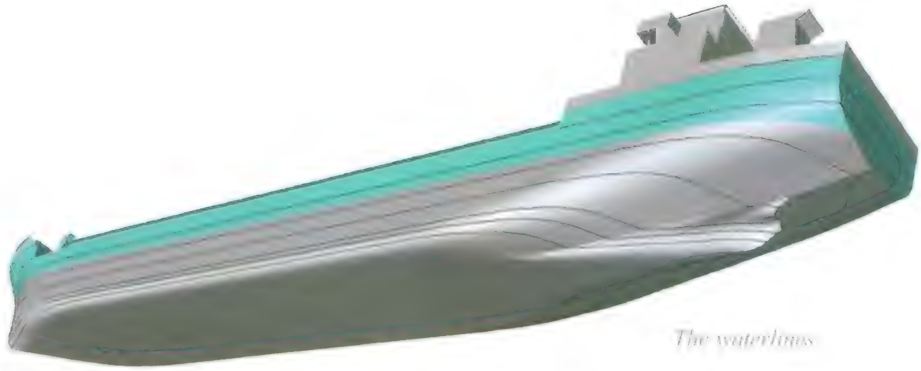
The shape of a ship can vary in height, length and breadth. In order to represent this complex shape on paper, transverse sections of the hull are combined with two longitudinal sets of parallel planes, each one perpendicular to the others.

Ordinates.
Evenly spaced vertical cross-sections in transverse direction are called **ordinates**. Usually the ship is divided into 20 ordinates, from the centre of the rudder stock (ordinate 0) to the intersection of the water line and the mould-side of the stem (ordinate 20). The boundaries of these distances are numbered 0 to 20, called the ordinate numbers. A projection of all ordinates into one view is called a frame plan.

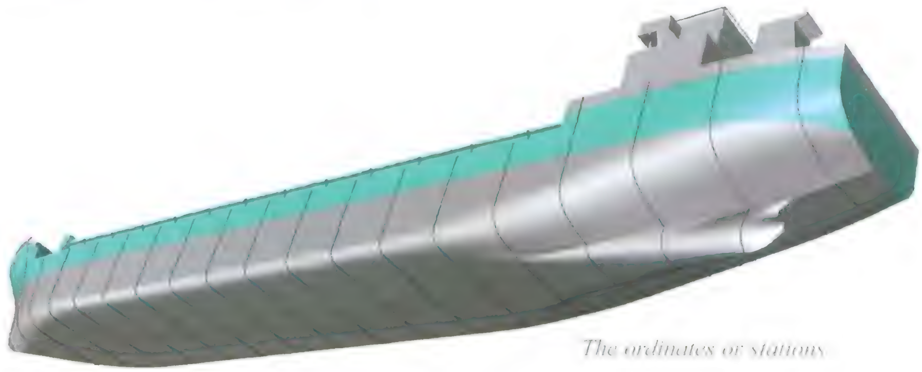
Water lines.
Horizontal sections of the hull are called **water lines**. One of these is the design water line. This is the water line of the ship at the level of immersion in full cargo. Between the baseline and the design water line are usually 3 to 4 other water lines drawn, counted from the baseline, which is called number 0. The **construction water line**, or the **scantling water line**, can be higher. When the water lines are projected and drawn into one view from above, the result is called a water line model.



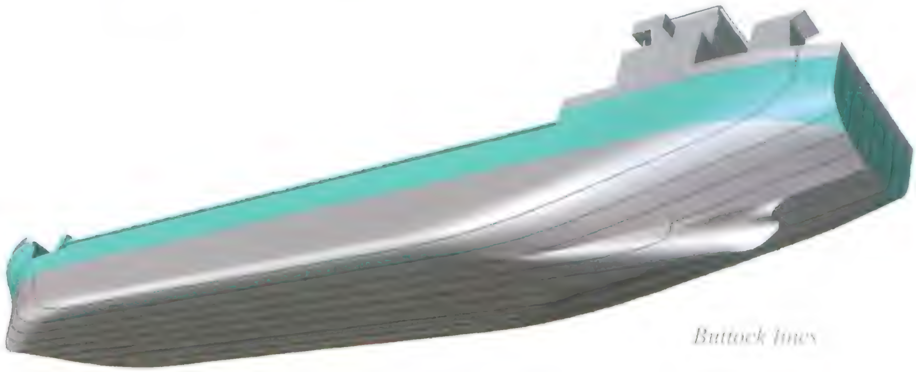
Verticals, diagonals



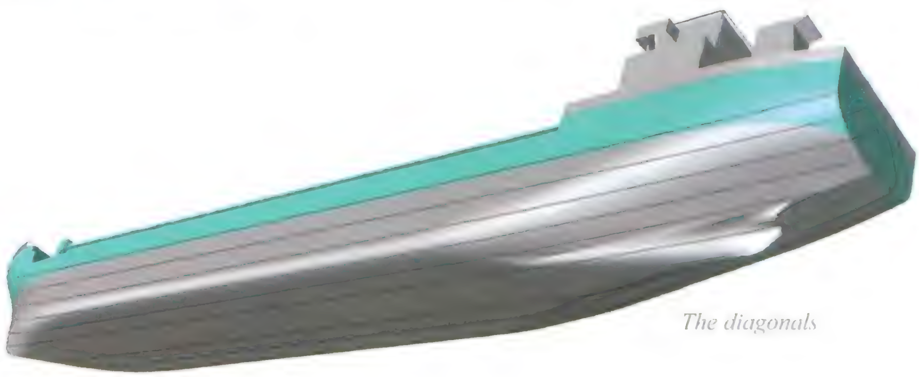
The waterlines



The ordinates or stations



Buttock lines



The diagonals

Verticals / Buttocks
Vertical sections in longitudinal direction are called **verticals** or **buttock lines**. These longitudinal sections are parallel to the plane of symmetry of the ship.
When the buttocks are projected and drawn into one particular view, the result is called a **sheer plan**.

Apart from the rectangular sections, sometimes planes are used, in longitudinal direction, but at an angle with the midship plane. They are called diagonals, or **sent-lines.**

Diagonals
The diagonals are longitudinal sections that intersect with the hull surface at a certain angle. On the longitudinal plan they show up as curves.

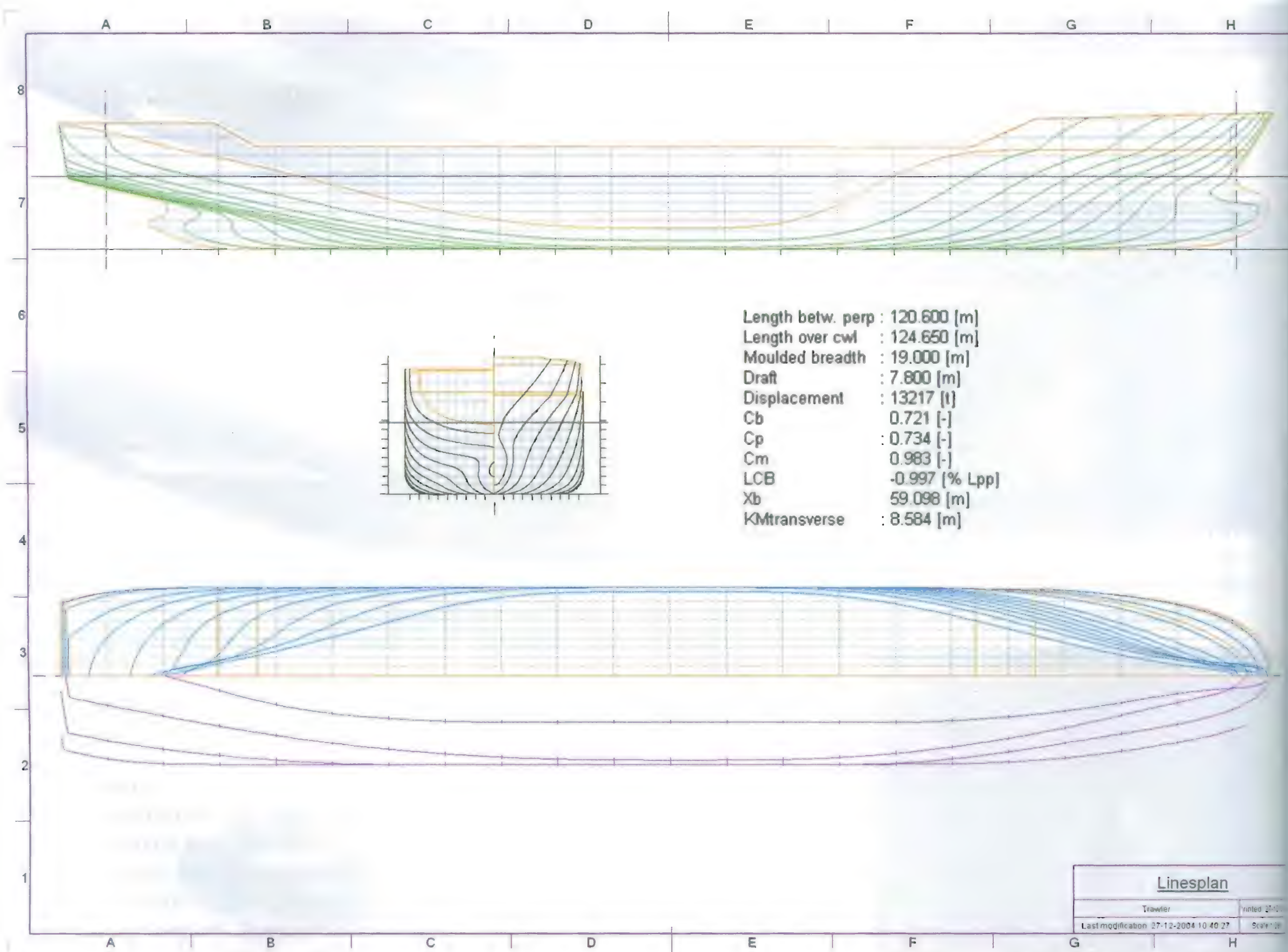
The curvature of the frames (ordinates), water lines and buttocks are compared to each other and modified until they are consistent, and develop smoothly in all directions. When this procedure is executed, the results can be checked using the diagonals. The most common diagonal is called the **bilge diagonal.**

Today the lines plans are made with the aid of computer programs that have the capability to transform the shape of the vessel automatically when modifications in the ship's design require this. When the lines plan is ready, the program is used to calculate, among other things, the volume, displacement and stability of the ship, set against draught.

As shown in the lines plan below, both the water lines and the verticals/buttocks are drawn in one half of the ship. In the body plan, the frames aft of the midships are drawn on the left side and the fore frames are drawn on the right. The lines plan is a moulded plan i.e. at the outside of the frames, thus inside of the shell plating.
The lines plans shown on page 35 and 36 are of vessels that have underwater bodies that differ quite drastically.

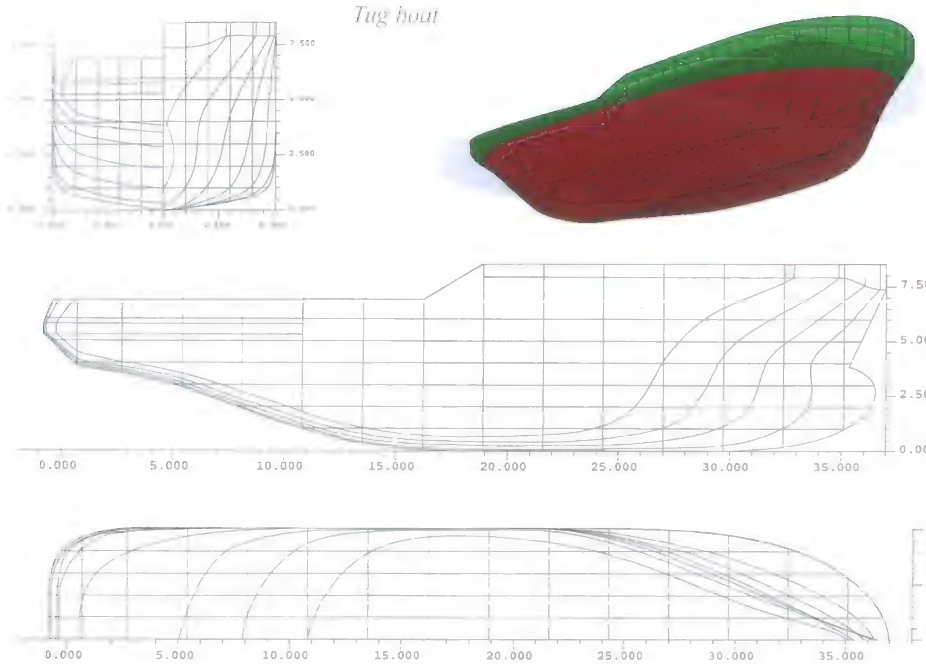
Ultra Large Crude Carrier

The reader can tell from these plans that a ship will be finer with smaller coefficients, when the water lines, ordinates and buttocks are more widely spaced. For instance, a rectangular forecastle has only one water line, one ordinate and one buttock, the coefficients are 1.



The lines plan of a trawler with a length over all of 124 meters

Tug boat

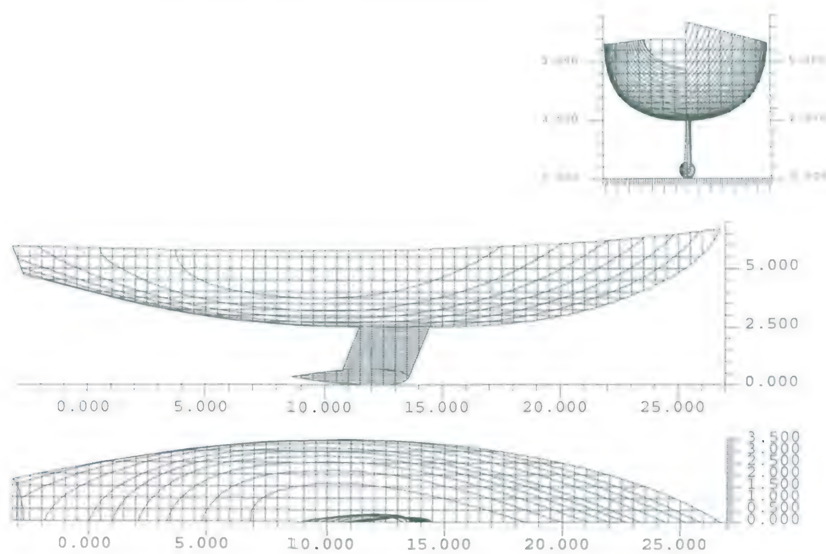


L_{pp} = 35 meter
B_{mld} = 10.08 meter
T_{mld} = 4.5 meter
Volume = 896 m^3
C_b = 0.565
C_m = 0.908

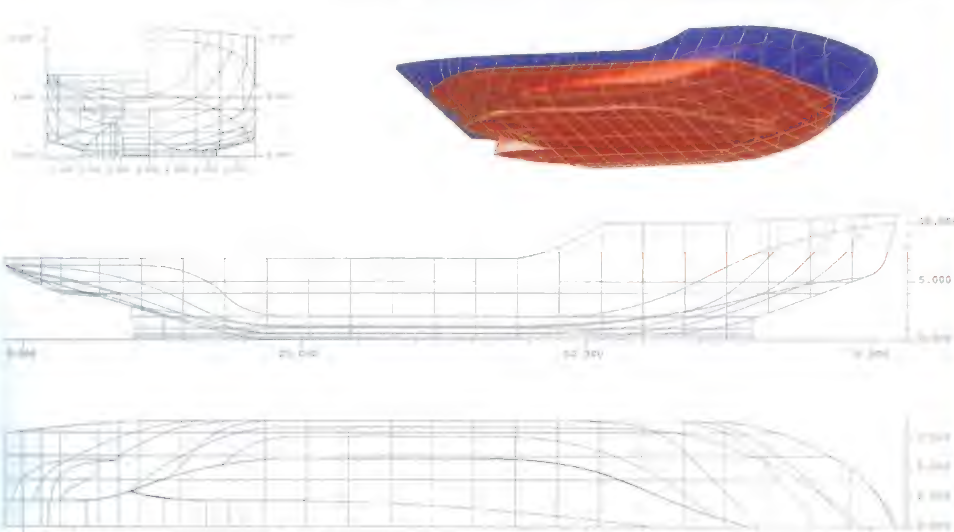
C_p = 0.622
LCB = 2.90 %
KM = 5.13 meter

Yacht

L_{pp} = 23.5 meter
B_{mld} = 6.25 meter
T_{mld} = 4 meter
Volume = 92 m^3
C_b = 0.157
C_m = 0.305
C_p = 0.515
LCB = -3.16 %
KM = 6.06 meter



Coast guard ship with a somewhat exceptional underwater-shape

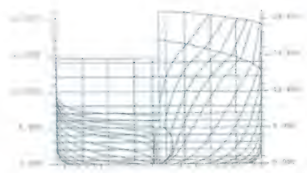


L_{pp} = 73.2 meter
B_{mld} = 18 meter
T_{mld} = 5 meter
Volume = 4196 m^3
C_b = 0.637

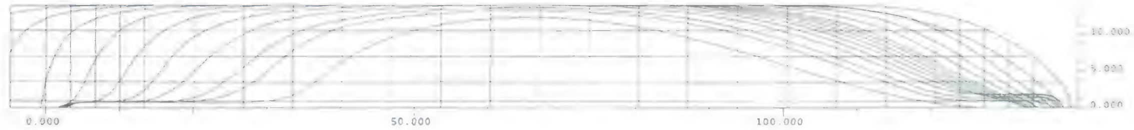
C_m = 0.933
C_p = 0.683

LCB = -0.75 %
KM = 8.67 meter

Heavy cargo ship, multi-purpose

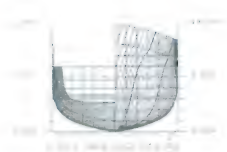


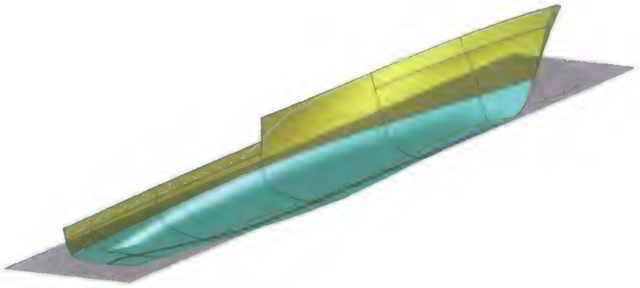
- L_{pp} = 134 meter
- B_{mld} = 28 meter
- T_{mld} = 7 meter
- Volume = 18644 m^3
- C_b = 0.710
- C_m = 0.992
- C_p = 0.715
- LCB = -2.24 %
- KM = 14.46 meter

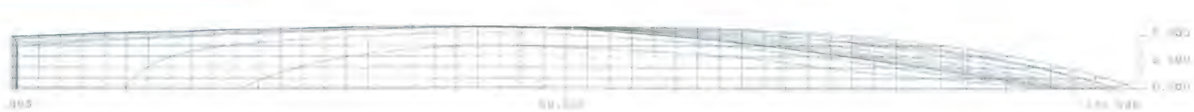


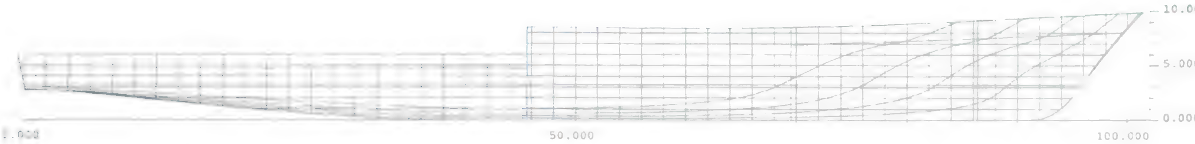
Frigate

- L_{pp} = 96 meter
- B_{mld} = 11.5 meter
- T_{mld} = 3.25 meter
- Volume = 1620 m^3
- C_b = 0.452
- C_m = 0.752
- C_p = 0.601
- LCB = -2.30 %
- KM = 6.17 meter









Abbreviations used in the drawings:

- L_{pp} = length between perpendiculars
- B_{mld} = breadth moulded
- T_{mld} = draught moulded
- Carène = volume of the underwater body, as measured on the lines, to the outside of the frames (m^3).
- C_b = block coefficient or coefficient of fineness
- C_m = midship section coefficient
- C_p = prismatic coefficient
- LCB = longitudinal position of the resultant of all upward buoyancy forces; Longitudinal centre of buoyancy (forward or aft of ordinate 10) in % of L_{pp}
- VCB = Vertical position of the resultant of all upward buoyancy forces;
- KM = Height of meta-centre above the keel (meter).

4 Drawings

4.1 Drawing list

To build a ship, hundreds of drawings are often needed. A selected number of drawings are to be submitted for approval to the Flagstate and the relevant Classification Society. The construction drawings have to be approved by the Classification Society, the drawings concerning safety in general by the Flagstate. Which drawings have to be submitted is depending on the type of ship.

Drawings have to be submitted to Classification and Flagstate.

Classification requirements:
- General Arrangement Plan,
- Lines Plan
- Construction Plan(s) Profile and Decks
- Transverse Sections, incl. Midship Section,
- Double Bottom Construction
- Fore and Aft ship,
- Rudder, Sternframe
- Engine foundation,
- Crane foundations, if applicable,
- Deckhouse
- Capacity Plan.
- Loading Manual for longitudinal strength
- Pumping and Piping,
- Shafting,
- Etc.

The Flagstate requires:
- General Arrangement Plan,
- Capacity Plan,
- Safety Equipment Plan,
- Stability calculations,
- All Class approved drawings.

Above very much depends on the flag the ship will carry. From one Flagstate to another, there are completely different requirements and can delegate it all to Class.

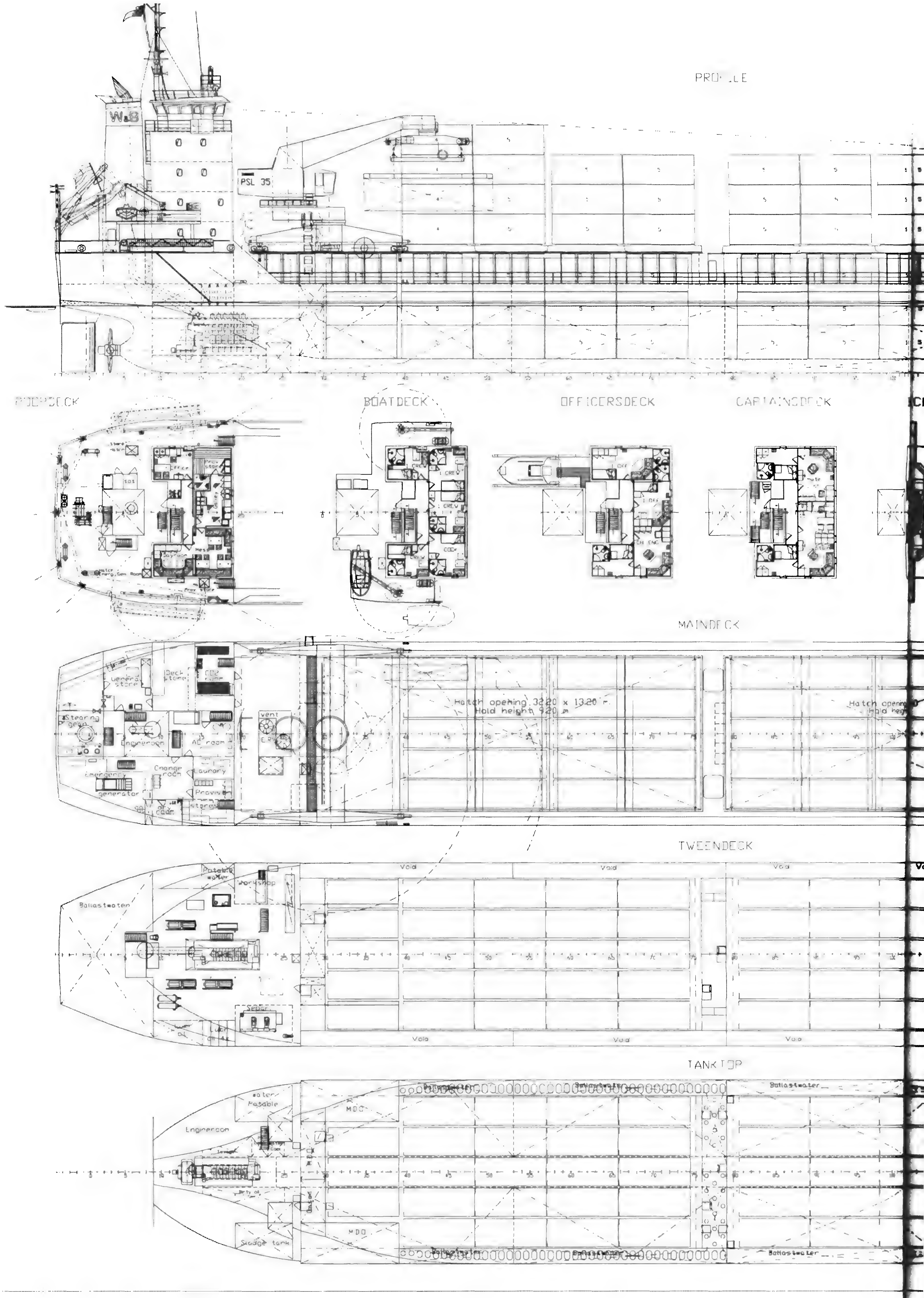
4.2 General Arrangement Plan

The General Arrangement plan roughly shows the division and arrangement of the ship.
The following views are displayed:
- a (SB) side-view of the ship
- the plan views of the most important decks
- sometimes cross-sections, or a front and back view are included

The views and cross-sections mentioned above, display among other things:
- the division into the different compartments (for example: tanks, engine room, holds)
- location of bulkheads.
- location and arrangement of the superstructures.
- major equipment (for example: winches, loading gear, bow thruster, lifeboat).

In addition to these, some basic data are included in the drawing such as:
- principal dimensions
- volumes of the holds
- tonnage
- deadweight
- engine power
- speed
- class.

The general arrangement plan of this ship is shown at the next pages


PROFILE
PSL 35
POOPDECK
BOATDECK
OFFICERSDECK
CAPTAINSDECK
MAINDECK
Hatch opening 32.20 x 13.20 m
Hold height 9.20 m
TWEENDECK
Void
Ballastwater
Workshop
TANKTOP
MDO
Engineroom
Sludge tank

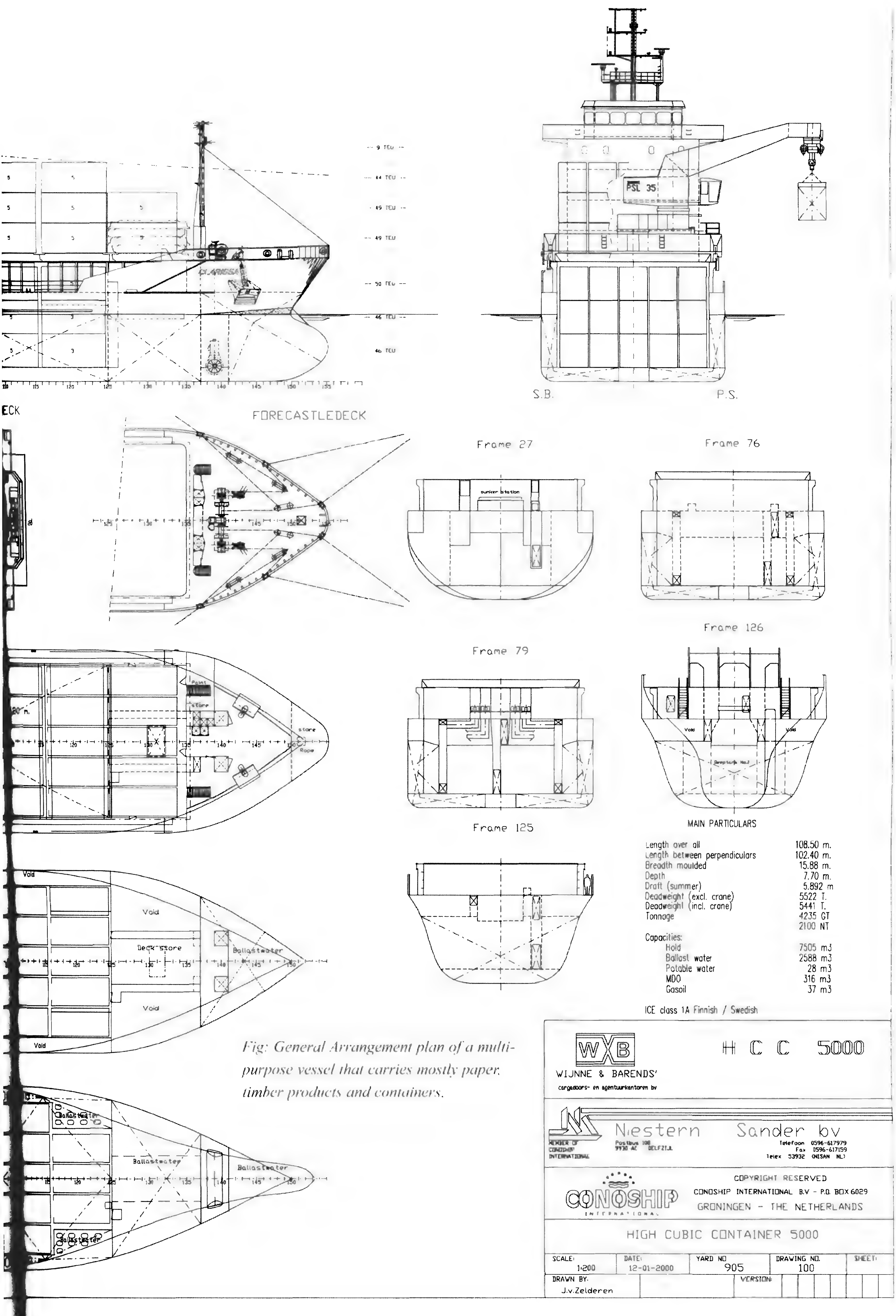


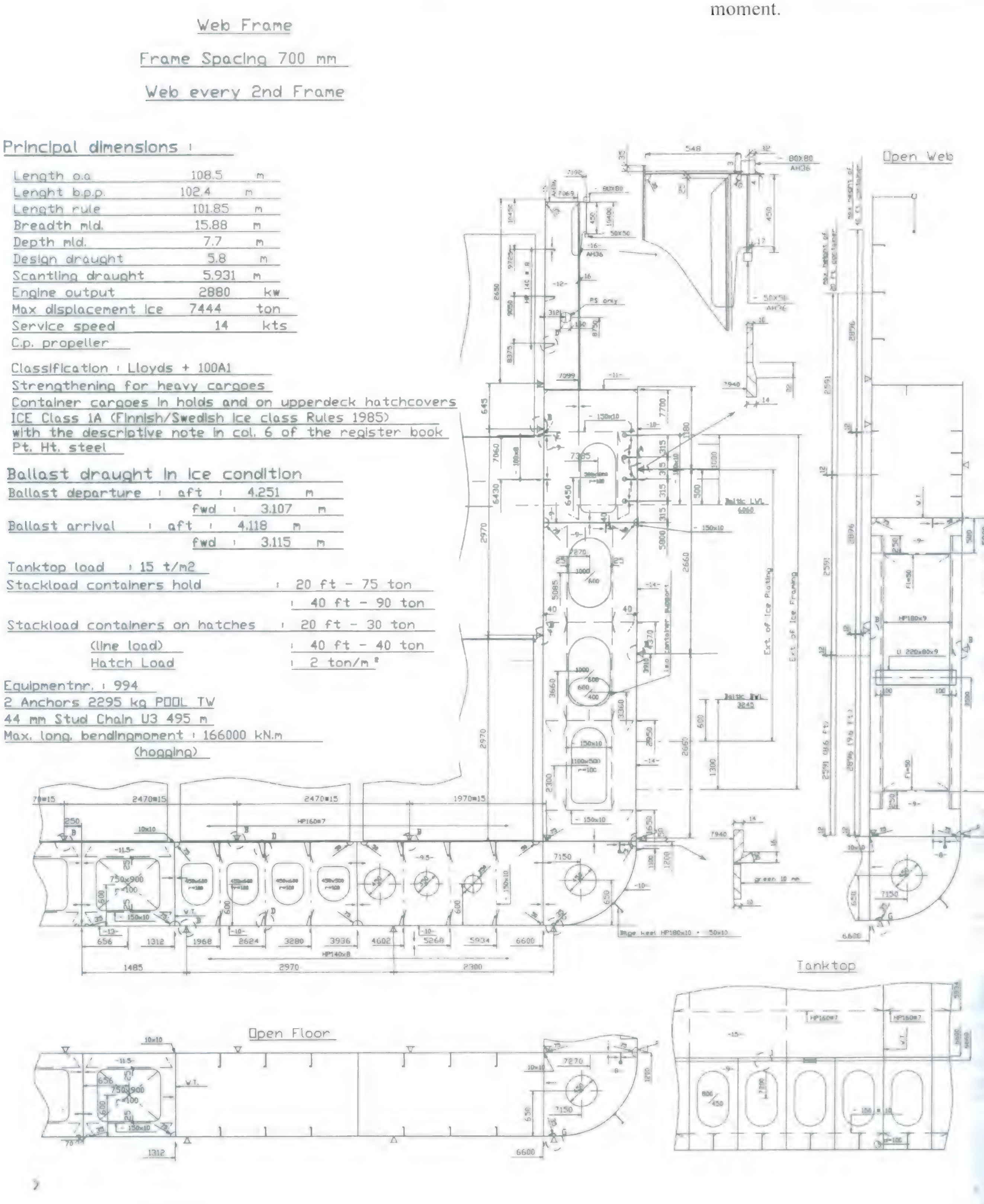
Fig: General Arrangement plan of a multi-purpose vessel that carries mostly paper, timber products and containers.

4.3 Midship Section

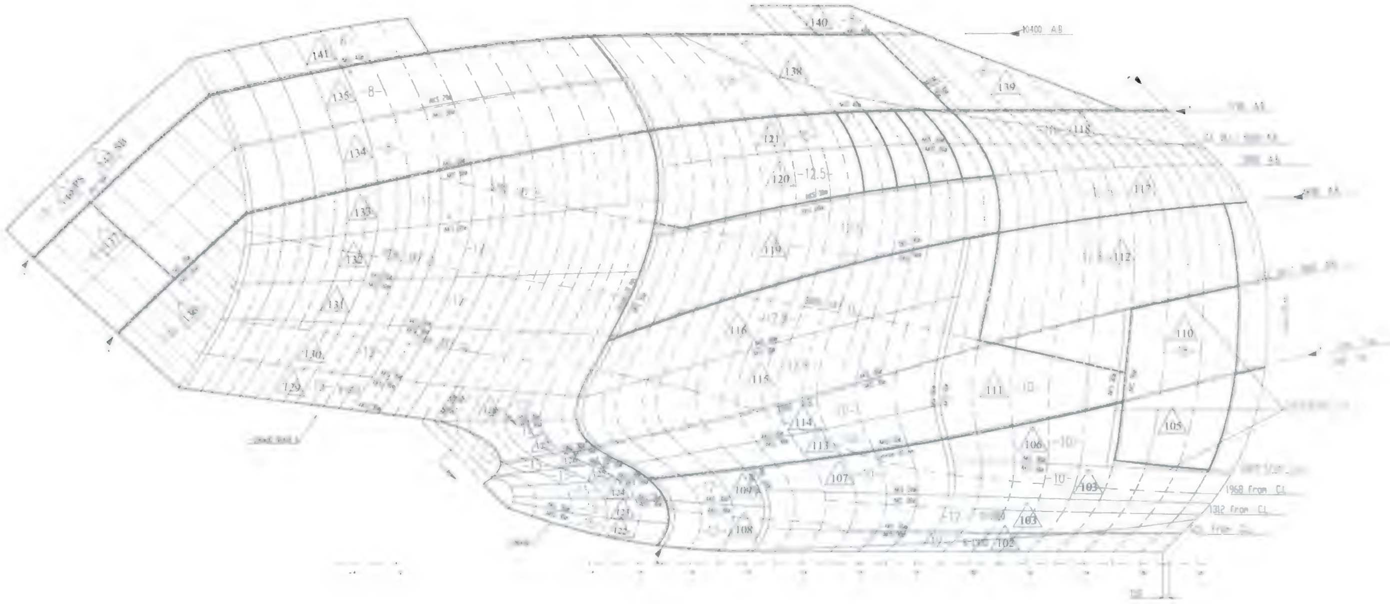
This cross-section shows one or more transverse sections of the ship. In case of a freighter it is always a cross-section of the hold near to the mid-length.

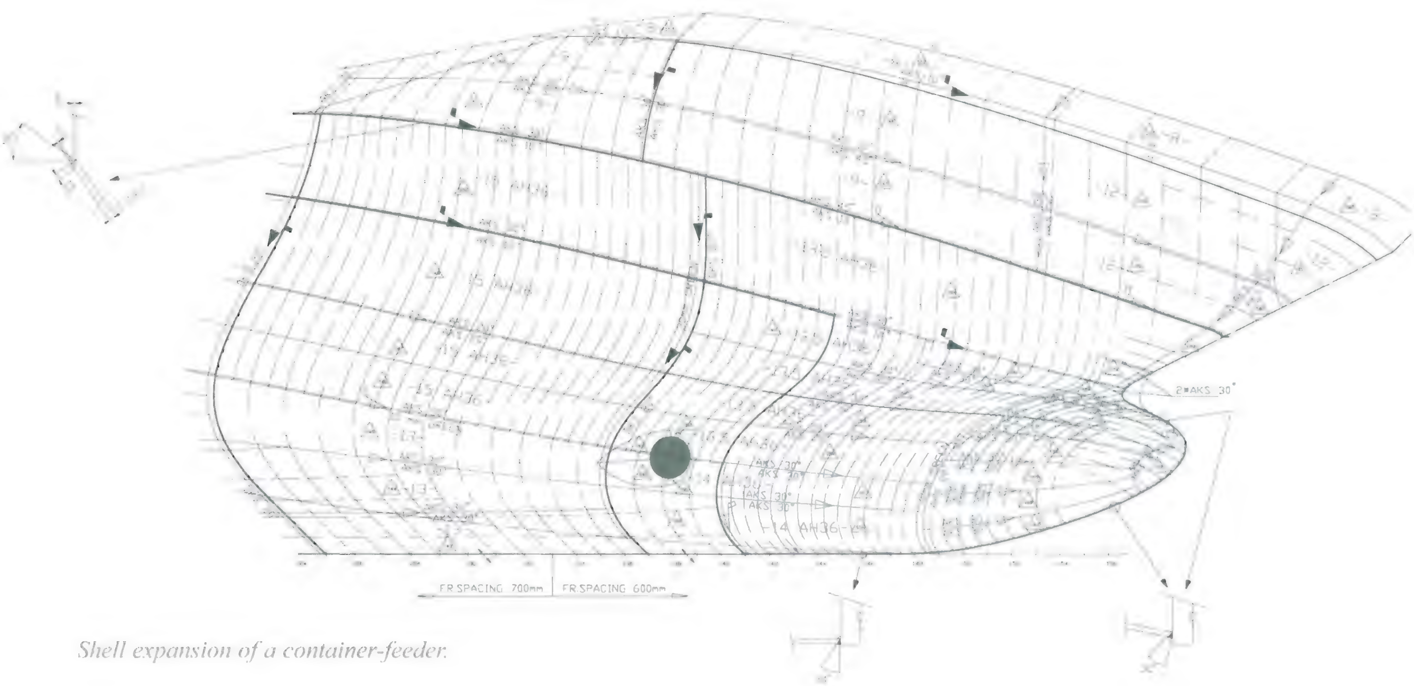
It shows the principal dimensions, quality and thickness, of shell plating, deck plating, all longitudinal stiffening, transverse frames and web frames, if applicable, and important data of equipment:

principal dimensions
- engine power and speed
- data on classification
- equipment numbers i.e. anchors and chain cables,
- maximum longitudinal bending moment.



Midship section of the HCC 5000 multipurpose ship





Shell expansion of a container-feeder.

4.4 Scantling Plan / Construction Plan

This drawing shows the longitudinal centreline section (CL) and the plan views of the most important decks. Sometimes the drawing also includes the watertight and other important bulkheads. It indicates their locations and the dimensions of the structural members (including the plate thickness). Sometimes the bulkheads are shown on the midship-section drawing.

4.5 Shell Expansion

In order to have information about the distribution of the different plates of the shell and other details (for example hull openings) over the complete hull, a **shell expansion** is drawn. At each frame number and at each level can be seen what quality and thickness of shell plate is fitted. This is very important in case repairs have to be carried out.

This drawing is usually made with the centreline of the bottom shell at its actual length as basis for the drawing. Each frame is drawn as a line perpendicular to this baseline, the frame spacing at scale apart, with a length of the total developed length (girth) from keel to rail, as if a rope had been drawn along the particular frame.
The seams and landings of shell plates are drawn, shell openings like sea chests, longitudinal internals, tank borders, decks, etc. are indicated each in a different way

4.6 Various other drawings

Double Bottom
The height and the length of the double bottom can be found on the Construction Plan, and the Midship Section. Where the tank top meets the shell can be seen on the Shell Expansion. The forward part, vulnerable to the impact forces due to the heaving movement of the ship, has increased scantlings.

Decks
The decks are important for Class, as far as they are part of the longitudinal strength calculation. The Midship Section gives most information, and also the Construction Plan. Decks in way of the neutral plane are less important.

Construction Aft / Engine room and Foundations

The Engine room construction is important, including the foundations of the various machinery, in connection with propulsion forces and vibration. Special drawings with the web frames and vertical structure are made of this part of the ship, normally called: Construction Aft

Safety Plan

The safety plan is a general arrangement plan on which all the safety devices such as lifeboats, life rafts, lifebuoys, hydrants, fire-hose boxes, escape routes, fire extinguishers are shown. See also under Chapter 15, Safety.

Docking Plan

The docking plan is a mixed version of the General Arrangement and the Capacity Plan.

It has to show where the ship should be supported by the dock blocks when it has to go in drydock. Important is the location of longitudinal and transverse bulkheads, rise of floor, and shellopenings, including drain-plugs, echo-sounder, log, etc.

Capacity Plan

This is also a simplified version of the General Arrangement. All tanks and holds are indicated with their volumes and corresponding centre of gravity.

Together with the stability and 'light ship weight' particulars, this forms the basis on which stability calculations can be performed. Normally this drawing goes together with the **Deadweight Scale**, which shows the relation between draught, freeboard, displacement, immersion per centimetre and deadweight in fresh and salt water.

Navigation Light Arrangement

The Navigation lights have to be installed in accordance with the International Regulations for Prevention of Collisions at Sea (lights and shapes), which describe the position and visibility range of the various lights. The arrangement has to be approved by Flagstate.

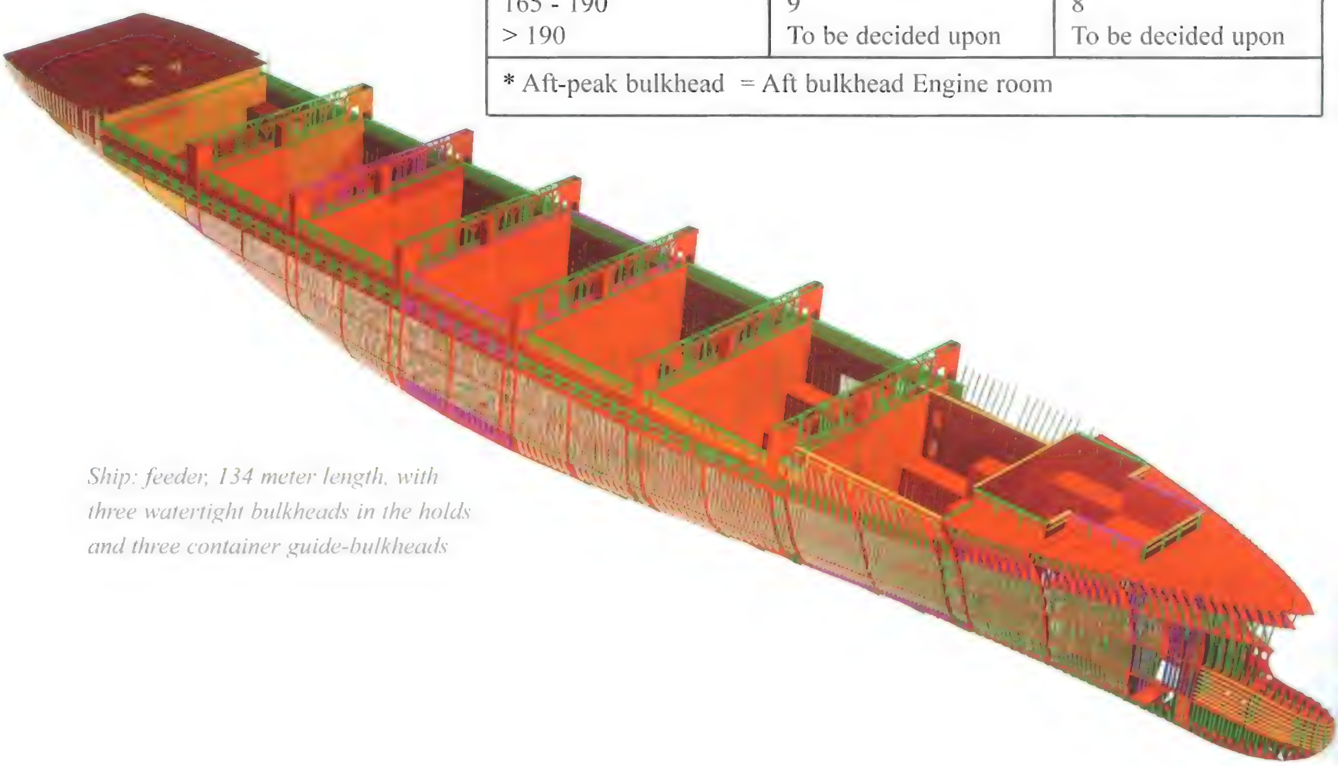
4.7 Bulkheads

Every ship has to be provided with watertight bulkheads. Minimum required: the forepeak-bulkhead (collision bulkhead), the aft-peak bulkhead, and engine room bulkhead(s).

The required minimum number of bulkheads of a ship is given in the following table, printed in the rules of the classification societies.

Alternative arrangements can be considered, depending on operational restrictions and adequate constructional compensation.

Length [m]	Engine room midships	Engine room aft *
< 65	4	3
65 - 85	4	4
85 - 90	5	5
90 - 105	5	5
105 - 115	6	5
115 - 125	6	6
125 - 145	7	6
145 - 165	8	7
165 - 190	9	8
> 190	To be decided upon	To be decided upon
* Aft-peak bulkhead = Aft bulkhead Engine room		



Ship: feeder, 134 meter length, with three watertight bulkheads in the holds and three container guide-bulkheads

5. Important data on various ships

Shipowners have an interest in promoting their ships as much as possible, especially the types of cargo their ships can transport. Or to put it in another way: how they can earn money. The tables on the following pages contain data of a number of ships which significantly differ in the type of cargo they can carry. The abbreviations and other information are explained, unless they have previously been explained in the text.

CLASS	**S-TYPE**	LLOYD'S + 100 A1 + LMC UMS LA NAV1	(1)
		strengthened for heavy cargoes	(2)
Ice Class Finnish/Swedish		1A	
PRINCIPAL DIMENSIONS			(3)
Length over all		168.14 m	
Breadth moulded		25.20/25.30 m	
Height in hold as SID		14.30 m	
Height in lower hold as TWD		3 height 3.30, 7.00 or 10.25 m	
Height in tween deck as TWD		3 heights 9.90, 6.20 or 2.95 m	
Design draft		10.00 m	
Max summer draft		10.65 m	
GT		abt 16,800	(4)
NT		abt 6,900	
DEADWEIGHT all told	design draft	abt 18,900/18,275 mt (excl/incl TWD)	(5)
	max summer draft	abt 21,150/20,525 mt (excl/incl TWD)	
CAPACITY	grain = bale	hold 0 14,000 cbft 400 m³	(6)
		hold 1 179,000 cbft 5,050 m³	
		hold 2/3 662,000 cbft 18,750 m³	
		total 855,000 cbft 24,200 m³	
		if tween deck installed 63,000 cbft/1,780 m³ less in holds	
FLOOR SPACE	tank top	total 1,625 (no 0: 50 m², no 1: 340 m², no 2/3: 1,235 m²)	(7)
	tween deck	total 1,840 m² (no 1: 425 m², no 2/3: 1,415 m²)	
	weather deck	total 2,800 m² (no 0: 50 m², no 1: 425 m², no 2: 685 m², no 3: 650 m²)	
AIR CHANGE (basis empty holds)		abt 20 x per hour	(8)
CONTAINER INTAKE			(9)
Hold	units	478 TEU	
Deck	units	632 TEU	
Total	units	1,110 TEU	
Max size		height up to 9'6", width up to 2,500 mm	
		limited quantity alternative dimensions such as length 45 ft	
Power available for reefer connection.		up to 800/900 kW	
SIDEPORTS		**5 side shifters, each 16t SWL, 500t capacity per hour**	
HATCHES	weather deck	no 0: 6.50 x 7.50 mno 1: 25.60 x 17.80/15.20 m	
		no 2: 38.40 x 17.80 m no 3: 25.60 x 20.40 m	
		steel, end folding type	
	tween deck	no 1: 25.60 x 17.80/15.20/10.10 m no 2: 38.40 x 17.80 m	
		under crossbeam: 4.20 x 17.80 m no 3: 25.60 x 20.40 m	
		consisting of 18 steel pontoons;	
Bulkheads/compartments		removable pontoons up to 14 compartments at TEU interval	
MAXIMUM LOAD			(10)
Weather deck hatch covers		1.75 t/m² weatherload, 2.00 t/m² payload	
Tween deck hatch covers		hold 1: 7.5 t/m², hold 2: 5,5 t/m², hold 3: 5.0 t/m²	
Tank top		20.0 t/m²	
DECK CRANES combinable			(11)
Tons/reach		**3 of 120 mt SWL/14m and 50 mt SWL/30m**	
Position		2 x PS (aft and mid) and 1 x SB (forward)	
MAIN ENGINE		Wärtsilä 16,400 HP/12,060 kW Bowthruster 1,155 HP/850 kW	(12)
Speed	design draft	abt 19.6 knots	
Fuel consumption per day		abt 45 mt IFO 380 cSt, no MIDO at sea, except for maneuvering	
BUNKER CAPACITY			
Intermediate Fuel Oil		1,700 m³	
Marine Diesel Oil		180 m³	
BALLAST CAPACITY		7,200 m³	

5.1 General Cargo Ship

Explanation on the previous diagram

Lloyd's	=	The Classification Society	(1)
+100A1	=	Built according to and under supervision of the rules of this Class.	
+LMC	=	Lloyd's Machinery Class. All machinery has been built in accordance with the specifications of this classification.	
UMS	=	Unmanned Machinery Space. The engine room does not have to be manned permanently.	
LA	=	Lifting Appliances. The cargo gear has been approved as classed.	
NAV1	=	Permission for a single bridge watch control, although SOLAS-rules only permit this in favourable circumstances.	
The vessel has been reinforced to carry heavy cargoes.			(2)
1A	=	Finnish/Swedish Ice-class.	
Length over all			(3)
Width / Beam Moulded			
Height in hold as SID	=	Height in hold as single decker (no tween deck)	
Height in lower deck as TWD	=	Height in lower hold as a tweendecker	
Height in tween deck as TWD	=	Height in the tweendeck as a tweendecker.	
Gross Register Tonnage			(4)
Net Register Tonnage			
Deadweight all told	=	Deadweight at design draught. Approximately 18900/18275 metric tons (excluding/including tween decks).	(5)
Capacity	=	Grain or Bale space. Because the hold is box shaped, the total m³ of bulk cargo equals the total m³ of general cargo.	(6)
Cbft	=	Cubic feet. If all the tween decks are installed in the hold, the capacity of the hold decreases by 63000 ft³ or 1780 m³.	
Floor Space	=	Deck area of the tank top, tween deck and weather deck overall and per hold.	(7)
Ventilation:	=	Number of air-changes per hour, with empty hold.	(8)
Container intake	=	The number of containers with a length of 20' that can be loaded.	(9)
Maximum height and breadth.	=	The inside measurements of the cargohold are, if practicable, based on a number of times the size of a container in length and width, with a little oversize.	
Maximum load	=	Minimum strength of the hatches (also according to class) as determined by the Load-line Convention. The criteria are based on the maximum height of a water column on the hatch, which is 1.8 metres. This figure is under discussion, the hatch covers of bulkcarriers are required to be made stronger.	(10)
Deck cranes (combinable)	=	The deck cranes can be combined (in twins) All three cranes can lift up to 120 tons if the jibs are topped to a reach of 14 metres. If they are lowered to a range of 30 metres, they can lift up to 50 tons. Position of the cranes: 2 on port side, one on starboard (fore).	(11)
Main engine	=	45mt IFO 380 cst (centistoke) = 45 tons intermediate fuel oil 380 centistoke (Centistoke is a measurement for the viscosity).	(12)
MDO	=	Marine Diesel Oil	

5.2 Refrigerated vessel

Flag:	Panama
Call sign:	H3EY
Lloyds No: **(1)**	9167801
Built:	2000
DWT: **(2)**	12.902 mt

GT/NT:	11.382/6.408
Loa:	155 meter
Beam: **(3)**	24 meter
Summer draught:	10,1 meter
Holds/Hatches/ Compartments: **(4)**	4/4/15
Ventilation/Air changes: **(5)**	Vertical / 90
Different temps: **(6)**	8/2 per hold
Cranes:	2 x 40 ton
Pallet cranes:	2 x 8 ton
Container capacity: **(7)**	294 TEU plus 60 FEU or 207 FEU
Reefer plugs: **(8)**	185
Speed banana laden: **(9)**	approximately 21.5 knots
Consumption (reefer plant): **(10)**	appr. 49 MT IFO 380 RMG 35
Aux: **(11)**	appr. 6 MT IFO 380 RMG 35
Tank capacity: **(12)**	1.800 MT IFO 380 RMG 35 150 MT MDO DMA
Additional Features:	Bowthruster

Explanation on the specifications

(1) Lloyd's number is also the IMO-registration number of the ship. Even after a change of ownership, this identification number stays with the vessel for the full lifetime.
(2) Deadweight
(3) Breadth
(4) The number of holds, hatches and compartments. Most holds have three tween decks resulting in a hold which is divided into 4 compartments.
(5) The ventilation is vertical. The entire hold capacity of air can be changed 90 times per hour.
(6) Number of isolated compartments where the temperature can be adjusted separately of the other compart ments; two per hold.
(7) The vessel can transport 294 Twenty Foot Equivalent Units + 60 Forty Foot Equivalent Units or 207 FEUs. (294/2 + 60).
(8) Ship can provide 185 containers with electric power.
(9) If the vessel is fully laden with bananas, the maximum speed is 21.5 knots.
(10) The daily fuel consumption (including the refrigerating plant) is approximately 49 tons of Intermediate Fuel Oil 380 cst, (at 50 °C) or specified as Residual Machine G-35, with a viscosity of 35 cst (at 100 °C).
(11) The daily fuel consumption of the auxiliaries is 6 tons.
(12) Capacity of the fuel tanks is 1800 tons RMG and 180 tons DMA (Distillate Marine Fuels, A is gas oil).

Opened hold of a reefer

Deck lay-out of a reefer

5.3 Coastal trade liner

Flag:	Dutch
Built:	1998 / 1999
Type:	boxed shape / sid
D.W.T.: (1)	2964 meterton
D.W.C.C Summer: (2)	2800 meterton
GT / NT:	2056 / 1168
L.O.A.:	88.95 meter
B.O.A.:	12.50 meter
Draught laden: (3)	04.34 meter
Air draught: (4)	09.30 meter
Classification: (5)	B.V. 1 3/3 E cargo-ship deepsea - BRG
Trading area:	unrestricted waters incl. river Rhine
Container intake (total):	108 teu
Cubic capacity GR / BA:	151.000 cbft
Movable bulkhead:	2
Tanktop strength:	15 mt/m²
Hatch strength:	1 mt/m²

Ventilation:	electrical, 6 airchanges p/
Dimensions of holds length/breadth/depth	
Hold 1:	62,40 x 10,24 x 6,75 mete
Dimensions of hatches	
Hatch 1:	62,40 x 10,24 meter
Tank capacity	
Fuel:	217 cbm
Ballast:	1307 cbm
Fresh water	24 cbm
Engine equipment	
Main engine:	Wartsila 8L20
Output:	1320 bhp
Consumption (about):	10.5 knots on 5.500 litres MG

Explanation on the specifications

(1) Deadweight
(2) Deadweight Cargo Capacity at Summer draught.
(3) Maximum draught
(4) Air draught at summer draught, if the (loaded) vessel is not at summer draught, additional ballast may be used.
(5) Bureau Veritas, the ship is built according to the Rules and Regulations of the classification bureau for this type of ship.

5.4 Ferry

Length o.a.:	172.90 meter
Length b.p.:	160.58 meter
Breadth moulded:	25.70 meter
Depth maindeck:	9.40 meter
Depth upperdeck:	15.10 meter
Design draught:	6.35 meter
Total power at MCR: (1)	44,480 kW
Trial speed at design draught:	28 knots
Passenger capacity:	1,600
No of passenger cabins:	160
Dead weight:	4.500 Ton
Trailer lane length: (2)	1.780 meter
Car lane length: (3)	450 meter

Explanation on the specifications

(1) Power of the main engine.
MCR = Maximum Continuous Rating.
(2) Maximum total trailer length available.
(3) Maximum total car length available.

5.5 Gas tanker

Present flag:	Dutch
Port of registry:	Rotterdam
Ship type:	LPG (1) Carrier S.P. (2) 9.3 bar -48C 2PG (3)
IMO number:	9031985
Dead weight (summer draft):	3566 tons
Cargo tank volume:	3200 m³
Main engine:	Deutz SBV 9M 628 1690 kW at 900 r.p.m.
Aux. engines:	Deutz/MWM TBD (4) 234V8 3x331 kW
Type of fuel:	MDO
Total cabins:	10
Required minimum crew:	10

Explanation on the specifications

(1) Liquid Petroleum Gas
(2) Safety Pressure
(3) Classification Notation
(4) Turbo Gas-oil

After lengthening Anthony Veder's gas carrier "Coral Actinia" with 24.05 m enough space was provided to install a second cargo tank, increasing cargo capacity with 1000 m³ to 3200 m³.

5.6 Chemical tanker

Imo Type II, Marpol - Annex I & II (1)

Built:	2000
Dwt m. tons:	6430 mt
GT:	4670
NT:	1679
Speed:	15.5 knots
L.o.a.	118.00 meter
Breadth:	17.00 meter
Draft:	6.45 meter
Cargo cap. 98.5 %:	6871 cbm
Type steel: (2)	duplex stainless steel
Ice class:	1A

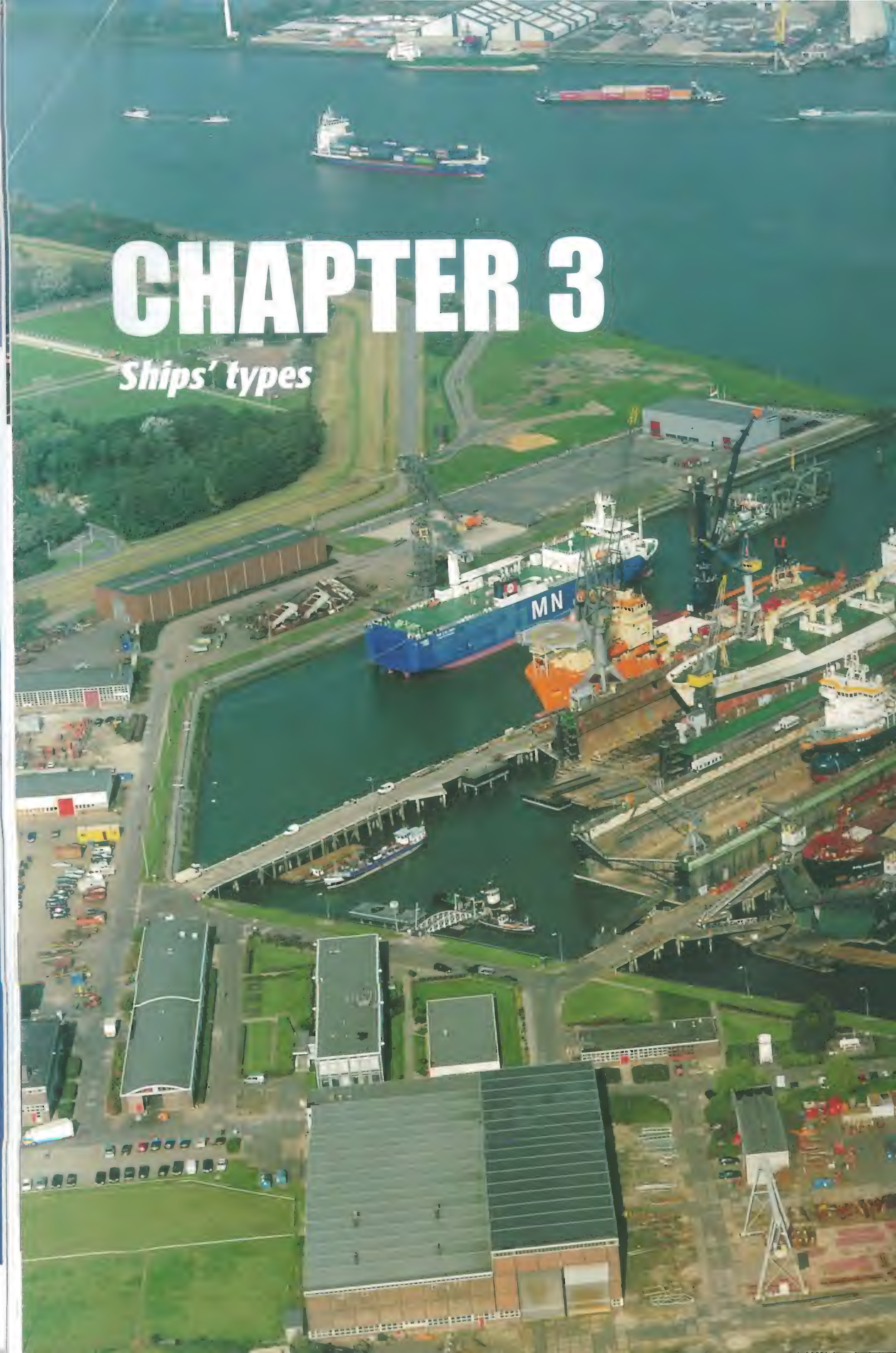
Exterior heating of cargo tanks up to 80 °C (3)
2 sloptanks cap. 206 m³ total

Explanation on the specifications

(1) Marpol requirements, Annex I: oil products, Annex II: liquid chemicals.
(2) The tanks are constructed of duplex stainless steel, which means that the steel plate of the tank surroundings is rolled in two layers: ordinary steel at the outside, and the stainless steel at the tankside.
(3) Sloptanks are tanks that collect the tank washing water.

CHAPTER 3

Ships' types



1 Classification of ships in types

In this table types of vessels are categorized in the table below. It is by no means a complete overview. Some vessels can be placed in more than one category.

SHIPS' TYPES

Dry Cargo (2.1)		**Liquid Cargo (2.2)**	**Passenger (2.3) ships**
Unit cargo – Container vessel – Roll-on/ Roll-off – Heavy-cargo vessel – Refrigerated ships – Cattle ship	**Bulk cargo** – Bulk carrier – Ore carrier	– Crude carrier – Product tanker – Chemical tanker – LPG / LNG carriers	– Passenger ship – Car and passenger ferries – Cruise ship
Multi-purpose ship			
Navy vessels (2.4) – Aircraft carriers – Cruisers – Destroyers – Frigates – Submarines – Mine sweepers	**Fishing (2.5)** – Trawlers – Other types of fishing vessels	**Dredgers etc. (2.6)** – Trailing hopper suction dredger – Cutter suction dredger – Rock-dumper	**Work ships (2.7)** – Crane vessels – Cable-layers – Buoy-layers – Oil-recovery vessels – Shear leg cranes
Auxiliary vessels (2.8) – Seagoing tugs – Harbor tugs – Icebreakers – Pilot vessels – Coast guard vessels – Research vessels	**Yachts (2.9)** – Motor yachts – Sailing yachts	**Various (2.10)** – Hydrofoils – Floating dock – Submersible platform – Pontoons, barges	**Offshore material (2.11)** – Drilling rigs/ Jack-up – Drill-ships – Pipe layers – Floating (Production) Storage and Offloading vessel F(P)SO

2 Brief discussion of several types of ships

The discussion of the vessels below includes a general description, dimensions and other characteristics. For example, important features for a container vessel are the maximum number of standard-containers it can carry and the deadweight. For a passenger ship, the deadweight is not important, but the number of passengers is. A tug has to deliver a high bollard pull, whereas that is not important for a dredger.

2.1 Dry Cargo

2.1.1 Multipurpose ships

Multipurpose means that these vessels can transport many types of cargo.

Pontoons are used to change the layout of the cargo hold in length and in height in accordance with the cargo. These pontoons can be fitted at various positions and heights, have a weight of approx. 20 tons and can be used as tween deck or bulkhead.

Usually the headledges and hatch coamings are of the same dimensions as the holds, which makes loading and discharging easier. The holds are closed with hatches using a variety of systems. Cargo such as wood or containers can also be carried on top of the hatches. Often the hatch-coamings and bulwarks are heightened to support the containers.

Possible cargo

- containers
- general cargo
- dry bulk cargo such as grain
- wood
- cars
- heavy items (project cargo)

Characteristics

- deadweight (t)
- hold capacity (m^3, ft^3)
- number of containers and their
- dimensions (20ft and/or 40ft)
- maximum deck load (t/m^2)
- maximum wheel-load (t)
- lifting capacity of cargo gear

Multipurpose vessels can be sub-divided into:

- ships with cargo gear (up to 120 tons lifting capacity per crane)
- ships without cargo gear
- coastal trade liners

A multi-purpose vessel can also be provided with one or more **ramps** on the side of the ship. Loading and discharging can then be carried out over these ramps by forklifts. This is faster and less dependent on the weather.

a. Ships with cargo gear.
Multipurpose ships with cargo gear are heavier than comparable vessels without cargo gear. As a result their carrying capacity is less. The advantage of such a ship is that she can work in ports and industrial zones where no cranes are available. A disadvantage is the increased air-draft which reduces the number of ports the ship can enter.

b. Ships without cargo gear.
Ships without cargo gear are dependent on the presence of loading gear in the ports and are therefore limited in their employability.

Multipurpose ship, no cargo gear, with hatch cradle

c. Coastal trade liners
In order to navigate from the sea into the inland waterways, coastal trade liners have a small draft; usually not more than 3.60 meters, a small air draft of approximately 6.5 meters and, compared to other ships of the same size, a large ballast tank capacity. Like inland vessels, coastal trade liners (also called sea-river ships) have masts which can be lowered and often a wheelhouse which can be adjusted in height. When the ship has to pass under a bridge, the wheelhouse can be lowered.

Additional characteristics.

- draft when loaded
- air-draft when loaded
- draft when not loaded
- air-draft when not loaded.
- ballast-tank capacity

Multi-purpose ship with its own cargo gear

Coastal trade liner

2.1.2 Container ships

Since the 1960s the transport of containers has continued to grow. The specific advantage of the use of containers is that the cargo can be transported directly from and to house or factory, and not just from port to port. Transport by water is just a link in the chain of transport.

Container vessels have grown from a capacity of 1500 TEU (1966) to approximately 13000 TEU (2007)

Possible Cargo
- containers (dry, liquid and reefer containers)

Characteristics
- maximum amount of TEUs or FEUs
- amount of TEUs or FEUs below the weather deck along with their heights
- number of container tiers
- presence of cargo gear
- open or closed ship

Sixteen containers beside each other

A container ship

The sizes of containers vary. The ISO-standards distinguish the TEU and the FEU, which may differ in height.
TEU = twenty feet equivalent unit. The nominal length of these containers is:

20' = 20 * 0.305 = 6.10 meters.

The actual length is 1.5" (38mm) shorter, leaving some space between the containers.
FEU = forty feet equivalent unit. The nominal length of these containers is :

40' = 40 * 0.305 = 12.20 meters.

There are two main types of container vessels:
a. Intercontinental container vessels up to 12000 TEU (2006)
b. Container feeders, starting at 200 TEU.

a. (Intercontinental) container ships
The big container ships can only go to the largest ports (main ports) because of the ships' size and the transfer capacity of the port.

Large container vessels usually do not have their own loading gear.

After 1991 a number of ships were built without hatch covers, also called hatchless or open-hatch vessels. Because there are no hatches it means that spray and rain water can enter the holds. Therefore the capacity of the bilge pumping systems has to be enlarged, especially to deal with tropical rain showers. This configuration has not been adopted generally The newest container ships are supplied with hatch covers.

Advantages of hatchless vessels:
- more efficient cargo handling which reduces the lay time and harbor fees
- guide rails, continuing above main deck level to keep the containers in position instead of lashings
- no hatch covers to be carried
- high freeboard and strong construction due to the guide rails

Disadvantages:
- the high freeboard has an adverse effect on the GT measurement of the vessel
- the price is high because of the amount of steel used and the intricate engineering

Like big tankers and bulk carriers, container vessels can also be classified on the basis of the passage criteria.

These designations are:
- **Panamax ships.** Ships with a width less than 32.3 meters. They have the maximum width with which they can still pass the locks in the Panama Canal.
- **Post Panamax ships.** These ships are too large to pass through the Panama Canal. Since 1988, container vessels have been built with widths exceeding 32.3 meters.
- **Suezmax** ships have a maximum draft of 19 meters, which allows them to use the Suez Canal. The Suez Canal is currently being deepened, which means that the SuezMax size will be larger in future.

b. Container feeders

Container feeders are small or medium-sized ships starting at 200 TEU. They are specialized in the transport of containers from small ports, the feeder ports, to large ports or main ports and vice versa, or for use in services which are not profitable for the larger container vessels. The feeders are sometimes equipped with cargo gear. Often, multipurpose ships are employed as container feeders.

Container feeder (note: hogging)

2.1.3 Roll-on/ Roll- off

a. Ro-Ro carriers

To facilitate the transport of mobile cargo, Ro-Ro vessels have continuous decks over the entire length of the ship. Due to the large area of these decks, the vessel loses its stability rapidly if a large quantity of water floods the (lower) decks after a collision, in the case of a damaged side door or by water due to firefighting, resulting in a huge free surface.

Therefore the safety regulations for these vessels have been made more stringent and refined in the last few years (2006) by the requirement of transverse division doors dividing the deck in compartments, where a free-water surface on the largest of these compartments is still not fatal for the ship's stability.

The tweendecks of these ships are often adjustable in height. Loading and discharging proceeds via ramps in the side or stern which form a watertight closure and also function as the driveway for the mobile cargo.


Small Ro-Ro freighter with vehicles in the holds and on the main deck

During loading and unloading, the ship lists easily, which, especially with a stern ramp, twists the ramps. To prevent this, a Ro-Ro is equipped with an anti-heeling system which automatically distributes water between two opposing ballast tanks, keeping the ship upright. To prevent movement of the cargo (on wheels) in bad weather, the vehicles are fastened using a lashing system. During loading and discharging additional ventilation is required to get rid of the exhaust fumes of the diesel-driven lorries and tractors.

b. Ro-Ro Car and Passenger ferries

Almost all ferries transport both passengers and vehicles, whether they are navigating inland waterways or oceans and seas. The vessels usually shuttle between two ports on a very tight schedule. The passengers drive their own cars on board via a ramp, which is either part of the ship, a movable ramp placed on the quay or a combination of these two. Ferries have the same type of decks as the Ro-Ro carriers, and therefore face the same problems when water floods the decks.

Possible cargo
- trucks and lorries
- passengers
- cars
- trains
- trailers (with containers)

Characteristics
- number of cars or trucks
- lane length
- height between decks
- number of passengers
- carrying capacity

Heavy lift vessel, also suitable as multipurpose ship

2.1.4 Heavy Lift ships

Heavy lift ships can be divided into:
- semi-submersible heavy-lift ships
- conventional heavy-lift ships
- dock-ships (semi-submersible)

The construction and stability allows the above ships to carry extremely large and heavy objects. The **semi-submersible** ships can sink by letting in water, till the main deck is sufficiently below the waterline to take large floating objects like drilling rigs on deck (float on / float off). When the water is pumped out, the cargo is lifted and the ship sails with the cargo as one unit. Lashing and securing the cargo needs to be carefully calculated and carried out.
The conventional heavy-cargo vessels are often fitted with their own loading gear.

However, this does not necessarily mean that these vessels are able to lift all heavy objects themselves. When there is no heavy cargo, the vessels can function as multipurpose vessels.

Possible Cargo
- heavy or bulky objects
- complete parts of factories
- drilling rigs
- multi-purpose / general cargo

Characteristics
- carrying capacity
- maximum deck load per m^2 and in total
- dimensions of holds and decks
- lifting capacity per crane and max. height above deck.

Semi-submersible ship offloading a Tension Leg Platform (TLP)

2.1.5 Refrigerated ships

Refrigerated ships (reefers) have refrigerated holds to transport cold fruit or vegetables, or frozen cargo. Modern refrigerated ships increasingly carry cargo in containers instead of on pallets. Refrigerated containers have a built-in refrigeration system, which can be plugged in to the ship's electricity system. Air is used to remove the excess heat from the refrigeration units and therefore the ventilation of the holds is very important. Refrigerated containers can also be transported by a container vessel.

When fruit is carried, it is not only the temperature that is being controlled, but also the composition of the air in the containers in order to control the ripening process of the fruit. An increasing number of reefers are taking on general cargo such as cars and trucks, as return cargo.

Compared to multipurpose vessels, reefers have:
- smaller hatch openings (length, width and height)
- more tweendecks
  loading gear with a lifting capacity up to about 40 tons.

Possible cargo
- fruit, vegetables (cooled, chilled)
- meat, fish (frozen)
- general cargo
- containers on deck and sometimes in the holds.

Characteristics
- carrying capacity
- tonnage
- temperature range
- cooling and freezing capacity
- range of atmospheric control / air changes per hour
- relatively high ship speed.

Refrigerated ship with cargo gear.

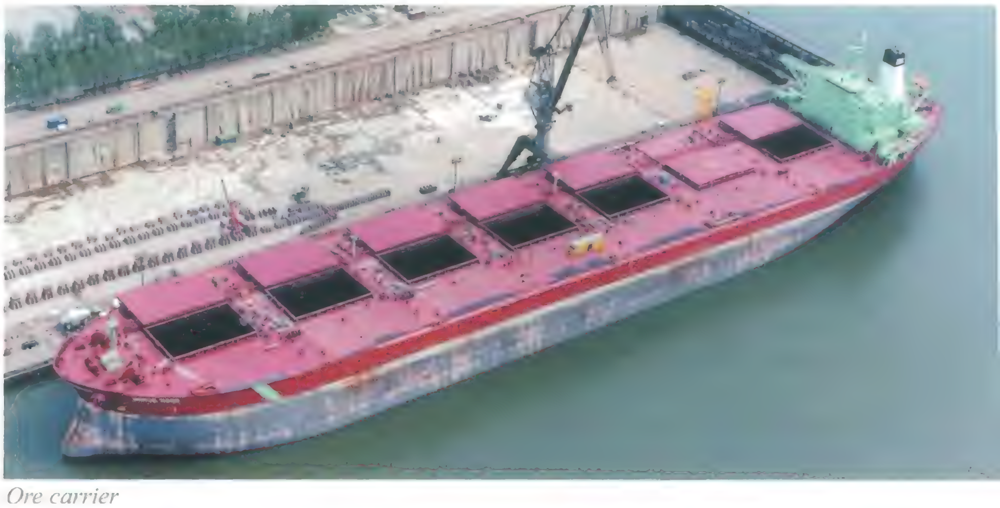
2.1.6 Cattle ships

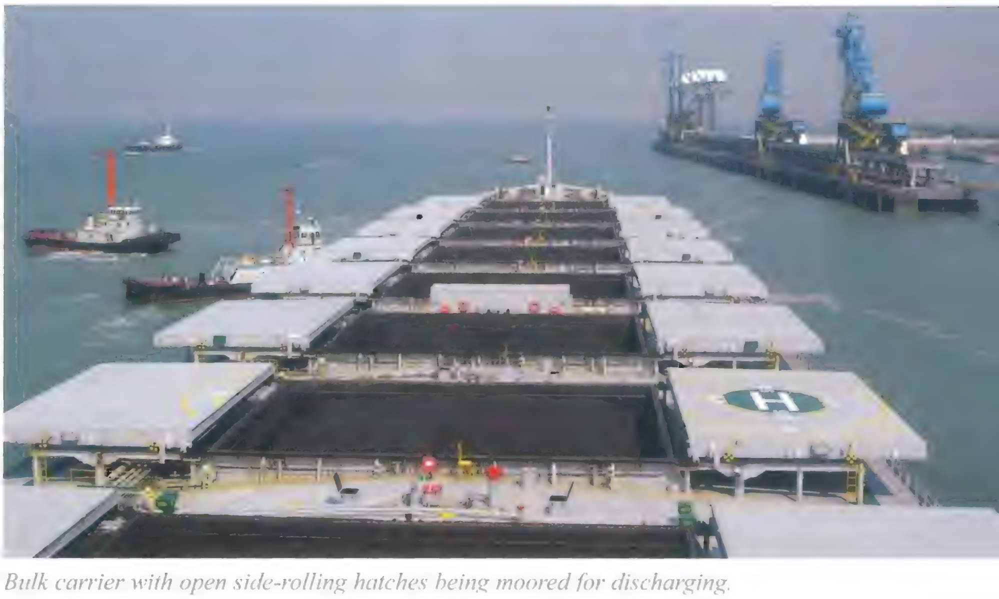
Cattle ships transport **livestock,** such as sheep from Australia to the Middle East. and cows from Northwest Europe to the Mediterranean. The holds are set up as stables. Silos with fodder are installed at the main or lower deck.
Sheep are often fed automatically, while cows are fed semi-automatically: the fodder is mechanically moved from the silo to the deck where it is distributed manually by means of wheel-barrows. A network of conveyor-belts and elevators dumps the manure overboard.
A proper ventilation system is required: at least 45 air changes per hour. Cattle ships need a low stability, with a long transverse period, i.e. a slender ship. This is to prevent the animals from breaking their legs due to the ship's rolling. The slender shape of the fore ship also prevents too much pounding.

Possible cargo
- livestock such as cows, sheep, goats, camels, horses etc.

Characteristics
- total deck area (m^2)
- stable system
- floor system
- manure discharge system

Cattle Ship


Ore carrier


Bulk carrier with open side-rolling hatches being moored for discharging.

2.1.7 Bulk carriers

Bulk carriers are specially designed ships that carry loose cargo in bulk. There are three types of bulk carriers:

a. **Handy size**, approx. 30,000 tons deadweight, often with their own cargo gear. Cargo: precious ore, sand, scrap, (china)clay, grain and forest products
b. **Panamax**, approx. 80,000 tons deadweight, seldom carry cargo gear.Cargo: grain and ore
c. **Capesize,** approx. 160,000 tons deadweight and over, no cargo gear. Cargo: coal, ore.

Bulk carriers are usually discharged by grabs or by suction pipes. Feeding occurs via a shooter or via a conveyor belt does the loading.

Bulk carriers have large upper and lower ballast tanks to facilitate automatic grain stowage (eliminate free surface) and to give the empty vessel sufficient draft and greater stability in transit.
Ships transporting ore have a special design. Ore is very heavy (stowage factor is approximately 0.5 m^3/t) and thus ships only need small holds to be loaded completely. To prevent too much stability the holds must not be situated too low or too close to the sides of the ship. Some bulk carriers can also function as tankers. This combination carrier is called an **Ore Bulk Oil (OBO)** carrier.

Possible cargo
- coal
- ore
- grain and other agricultural products
- fertilizer
- cement
- light minerals

Characteristics
- carrying capacity (t)
- cargo volume (m^3)

Crude oil tanker

2.2 Liquid Cargoes

2.2.1 Crude oil tankers

Crude oil tankers are used to carry crude oil from a loading port near an oil field or from the end of a pipeline to a refinery. The carrying capacity of crude oil tankers has risen to as much as 500,000 tons. Contrary to product tankers, crude oil tankers have a limited number of tanks, usually approximately 18 - 21 tanks plus two or three slop tanks.

Nowadays, tankers are provided with a double hull. This means that the side tanks and the double bottom tanks, which surround the cargo tanks, are ballast tanks only. The double hull prevents the cargo from leaking into the sea, and thus polluting the sea, when the shell is punctured through e.g. a collision or grounding.
The ballast tanks can contain sufficient ballast water to achieve a proper draft and trim even when there is no cargo on board.
A disadvantage of the double hull design is that the ballast tanks are difficult to reach. This is especially problematic when there is leakage between the ballast and cargo tanks. Ventilation, which is essential before entering, and cleaning of the tanks is also very problematic

The large crude oil tankers are subdivided into the following classes:
- **Ultra Large Crude Carrier (ULCC)** > 300,000 dwt
- **Very Large Crude Carrier (VLCC)** 200,000 - 300,000 dwt
- **Suez max (old max Suez draft)** ca. 150,000 - 160,000 dwt
- **Aframax** (Standard size tanker of ca. 105,000 dwt.)

Crude oil is the raw product as pumped out of the earth, with the water and sand removed.

The deep draft of VLCCs and ULCCs restricts the sailing routes and limits the number of ports that can be called at for loading or discharging.

Crude oil tankers load their cargoes through pipelines, hoses or flexible pipes, either at a shore facility or at a mooring buoy.

The hose(s) or hoses is/are temporarily connected to transverse pipes on deck, at mid length, the so-called manifold.
The oil is pumped on board by shore pumps. From the transverse lines, the oil goes down verticaly through drop lines, into the ship's, bottom lines.
Three or four longitudinal pipelines with branches deliver the oil to any tank. At the end of each branch a valve is installed. The bottom lines are connected to the pumps in the pump room, a space between the cargo tanks and the engine room.

To discharge the cargo, the ship's pumps draw the oil from the cargo tanks, pressing it upwards to the deck lines, and then to the manifold.
The oil is pumped through hoses ashore to the receiving facility, where the cargo ends up in a shore tank. Loading and discharging takes some 24 to 36 hours per operation.

Apart from the cargo pipeline system there are various other cargo related pipeline systems on deck and in the tanks:
- **Inert gas system** to fill up the empty space created while discharging with inert gas. (a gas with no oxygen) in order to prevent explosions. Oil will not burn as long as the percentage of oxygen stays below 5%.
- **Tank-wash system** used to remove deposits from the inside tank wall before repairs, docking or reloading. During discharge, the tanks and cargo are washed to reduce sediment. Before dry docking or repairs, tanks are washed with water, through the same system, to clean the tanks for entry (the tanks have to be ventilated extensively after the washing). Tank washing sometimes needs to be done with hot water.
- **Heating coil system** in at least the slop tanks. Usually crude does not need to be heated during the voyage.
- **Ballast system**, to fill and empty the ballast tanks, which is completely separated from the cargo system.

Possible cargo
- crude oil

Characteristics
- carrying capacity (tons)
- tank volume (m^3)
- discharging speed (m^3/hour)
- maximum laden draft (meter)

2.2.2 Product tankers

"Product" refers to the products of refineries and the petrochemical industries, as opposed to crude oil. Product tankers have a large number of tanks with a total carrying capacity of approximately 50,000 tons. The piping systems on a product tanker are different from the systems in crude oil tankers. Normally every tank has its own simultaneously filling and discharge line to the manifold and its own cargo pump. This in connection with many different cargo parcels on board. The ballast is carried in tanks surrounding the cargo-tanks, similar to crude carriers.

Possible cargo
- oil products like gasoline, kerosene, naphtha, diesel oil, lubricating oil, bitumen
- vegetable oil
- wine
- orange juice

Characteristics
- carrying capacity (t)
- total volume and volume per tank (m^3)
- number of cargoes which can be on board simultaneously
- coating or quality of internal tank surface.

Product Tanker in Panama Canal

Chemical tanker

2.2.3 Chemical tankers

Chemical tankers are basically product carriers with tanks of a higher safety grade, i.e. a wider distance between tank and outer shell or bottom. Also tanks are subject to more stringent restrictions, depending on the cargoes the ship is allowed to carry, in connection with the toxicity and flammability of the typical chemical cargo.

All cargo tanks are separated from:
- the outer-shell by a ballast tank
- the engine room bulkhead by a coffer dam, mostly in the form of a ballast pump room
- the forepeak bulkhead by a coffer dam.

This ensures that in case of leakage from one of the tanks, the vulnerability of crew and environment is reduced.

To prevent contact between incompatible cargoes, a coffer dam separation is sometimes required between tanks.

The GT of chemical tankers varies between 2500 and 23,000. The number of tanks in transverse direction varies between 3 for tankers up to 6000 tons and 6 for larger tankers.

Chemical tankers are divided in classes, depending on the protection the ship offers against pollution:
I for the most toxic cargoes, II en III for less dangerous substances.

The cargoes are divided in classes of toxicity:
A, B, C and D
A is the most toxic and D the least. IMO has decided in what category each liquid chemical is listed, and what category ship is allowed to transport that cargo.

Possible cargo
- acids
- alkalines
- alcohol
- edible oils
- chlorinated alkenes
- monomers
- chemical substances
-

A coffer dam is a narrow, empty space fitted between two other spaces, to create a safe division, provided with a sounding pipe, a bilge connection and a connection with open-air.

Characteristics
- carrying capacity
- number of tanks
- tank coating / Stainless steel

2.2.4 LPG / LNG tankers

Gas tankers are basically chemical tankers for cargoes which would be gas under ambient temperatures and atmospheric pressure. These cargoes are liquid when pressurized or brought under low temperature. **When liquefied, the space a gas takes is about 1/600 of the space needed under atmospheric conditions.** Gasses are therefore transported in liquefied condition. Safety devices applicable to chemical tankers are also applicable on gas tankers. The cargo storage arrangements however, are totally different. Cargo handling is somewhat different.

This type of cargo ship can be divided in three main-categories:
- Pressurized ships, cargo under pressure at ambient temperature
- Fully insulated / fully refrigerated ships, cargo at atmospheric pressure at low temperature.
- Semi-Pressurized ships, cargo at low temperature and under pressure.

The first category include relatively small ships: 500 to 6000 m^3 tank capacity, and the second group of ships can have as large as 190.000 m^3 tank capacity.

LNG-tanker (Moss-Rosenberg Principle)

Fully Pressurized (FP) ships are mostly used for **Liquefied Petroleum Gas** (LPG) transport between the smaller terminals. The largest ships are 10.000 m³. Fully pressurised means, that the cargo is carried in closed cylindrical tanks, under ambient temperature, with such pressure that the cargo is liquid in the tank, like in a butane cooking gas bottle. In case of LPG, this means a pressure of 8 Bar in moderate temperature up to 15 Bar under tropical circumstances.

Fully Refrigerated (FR) ships carry cargo under atmospheric pressure at very low temperature. In case of LPG, this means minus 42 °C , the boiling point of propane. LPG is a mixture of propane and butane, with boiling points of minus 42 and plus 0.5 °C respectively. LPG ships are up to 80.000 m³.

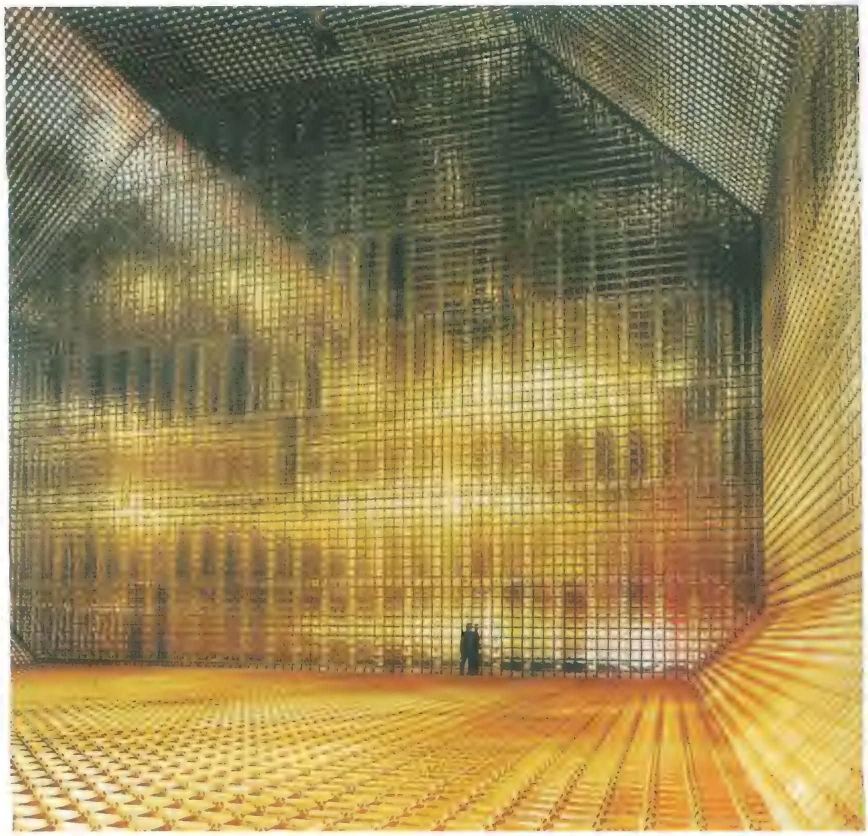
A special type of fully refrigerated ship is the **Liquefied Natural Gas** (LNG) carrier. When carrying LNG at atmospheric pressure, a temperature of minus 162 °C is needed, as LNG is a mixture of methane and ethane. Under atmospheric pressure methane has a liquefying point of minus 161 °C and ethane of minus 88 °C. These ships are used solely for LNG.

Other similarly liquefied gases can also be transported by FR gas tankers.

Semi Pressurized / Semi Refrigerated (SP/SR) ships are a hybrid type between Fully Pressurized and Fully Refrigerated (FP/FR). They were designed when materials became available which could withstand low temperatures, the cryogenic steels. When a cargo that would normally produce high pressure at ambient temperature is kept under cooled condition, the pressure it develops is much lower.

This makes it possible to carry a large number of different cargoes. The cooling capacity determines which cargoes are mentioned on the list of approved cargoes.

The development of this ship-type started with Semi Pressurised / Semi Refrigerated ships (SP/SR) later with Semi Pressurized / Fully Refrigerated ships (SP/FR) up to 30.000 m³ and pressure up to 8 Bar.



Hold of a LNG carrier (membrane type)

Ethylene carriers are a development of SP/FR tankers. The necessary cargo temperature is minus 104 °C

In all gas tankers the tanks are kept under, at least, a small positive pressure to prevent air from entering the tank, which could create an explosive mixture. Loading and unloading is carried out in a completely closed system, allowing no venting or vapors to can escape into the atmosphere. During loading of LNG, a vapor return line is used, the vapor is liquefied ashore and is not lost. When loading LPG, the vapor is re-liquefied on board.

The gas-cargo is carried in independent tanks. This means that the tanks are installed in a hold on supports that are mostly wood, with wooden supports for sideways forces. In case of leakages, the very cold liquid should never come in contact with the primary construction. Therefore, barriers are arranged, the primary barrier being the tank itself.

A secondary barrier is required in case of leakage for cargoes below minus 10 °C. Depending on the temperature and pressure of the cargo, rules are stipulated.

Tanks are constructed in 4 types:

- Fully refrigerated, atmospheric. Tank of flat panel construction, inside a hold. Intended for cargoes up to minus 10 °C. The secundary barrier is the hold, which is kept under inert gas.
- Fully refrigerated, atmospheric. Spherical steel tank, placed in a hold, sometimes hanging from an expansion ring at mid-height. The secundary barrier is the hold, where the atmosphere is allowed to be air, however, inerting should be possible at short notice.
- Cylindrical, horizontal tanks, at ambient temp. The cargo fully pressurized (max 18 Bar), insulated to prevent increase of pressure. This type of tank is used on SP/FR ships and on ethylene carriers.
- Box-type Membrane Tanks, with a very thin special stainless steel primary barrier, supported by a thick layer of foam insulation, inside a steel secondary barrier, again surrounded by insulation. The whole assembly is placed in a hold on blocks.

To keep the cargo cold, a small percentage is allowed to vaporize, called **boil-off**.

LPG tanker

A luxury cruise ship

In LPG and Ethylene tankers the "boil-off" is collected and by compressing and cooling in a condenser, reliquefied. By letting this condensation expand above the cargo, the whole cargo is cooled and brought to the desired temperature for transport and discharge. This is the single stage cooling cycle. A cascade cooling process (a multiple-step process) is used to reach lower temperatures by using cargo or another refrigerant, such as propylene, in a secondary cooling cycle as a coolant in the initial stage condenser.
The cargo pumps have to be deep well pumps.

In the past, large LNG tankers were steam turbine ships. The boil-off of the cargo could then be used as fuel in the boilers. The latest LNG tankers are provided with re-liquefying plants, compressing the boil-off into liquid gas again. Due to the high gas prices nowadays this is feasible. Today the propulsion of LNG tankers is changing from steam to diesel-electric, where one or more diesel engines are dual-fuel; depending on the price of gas and fuel, they burn either heavy fuel or boil-off gas.

Possible cargo
See above, depending on the design.
Characteristics
- total tank capacity (m^3)
- maximal tank pressure
- minimal cargo temperature
- maximum quantity in the tanks
- time needed for loading and discharging
- type of cargo tank
- lowest acceptable/achievable cargo temperature
- cooling down time
- inerting capacity (Nitrogen)

2.3 Passenger Ships

2.3.1 Cruise ships

Except in some archipelago areas, such as the Philippines and Indonesia, the traditional passenger liners have disappeared. International and intercontinental transport of passengers is now almost completely done by aircraft. The modern cruise ships are used for making luxurious holiday trips to distant countries and ports. On board there is a whole range of facilities for relaxation such as swimming pools, cinemas, bars, casinos, theatres, health clubs, etc.

Possible cargo
- passengers

Characteristics
- maximum number of passengers
- number of cabins according to size, luxury and location.

Without exception, these vessels are equipped with very good air conditioning systems. **Stabilizers** or anti-rolling fins limit the rolling to 2°, ultimately 4°. These ships are often highly maneuverable due to azipod propulsion systems.
Even modern cruise sailing ships have no noticeable list when sailing. The number of persons on board can be as high as 4000; the crew is half or two-thirds that number.

2.4 Navy vessels

2.4.1 Aircraft Carriers

Aircraft carriers are medium to large-size designed vessels used for take-off and landing of specialized aircraft and helicopters.
- CTOL (Conventional Take Off and landing). Aircraft carriers usually need catapults, driven by steam power to accelerate an aircraft sufficiently for take-off. Take-off is done from the bow, in forward direction, usually with two catapults beside each other. Brake-cables are installed to catch the landing aircraft. The landing strip is laid at an angle of approximately 25° with centerline to facilitate take-off and landing simultaneously.
- STOVL (Short take-off and vertical landing) aircraft carriers are smaller than CTOLs. They use a sort of ski jump for greater lift during take-off and do not have the auxiliaries that CTOLs have. Helicopter carriers just have a flat deck.

2.4.2 Cruisers

Cruisers commonly have a displacement of more than 10,000 tons and are sufficiently armed to operate on their own. Tasks are surveillance, blocking, protection of convoys and supporting large fleets.

2.4.3 Destroyers

A destroyer is smaller than a cruiser but is also fitted to operate independently. These are multi-functional warships designed to fight submarines and surface vessels and to escort convoys.

Frigate

Mine hunter

Support vessel

2.4.4 Frigates

Frigates are very versatile warships. They are suitable for air defense, anti-submarine warfare and surface warfare. They have a wide array of sensors, communication devices and large numbers of sonars. There are several different weapon systems on board which are controlled from the command room and can follow and attack a target fully automatically.

Frigates are often equipped with a helicopter landing platform. The ships have a length of about 130 meters and a crew of 150. The vessels are lightweight, highly maneuvrable ships with a large propulsion power (gas turbines) divided over two engine rooms. At a speed of 30 knots they can come to a complete stop within 1.5 ship-lengths.

2.4.5 Corvettes

Corvettes have a displacement of 700 to 2000 tons and are well armed. They are best equipped to act in regional operations and are seldom used for long-range operations.

2.4.6 Submarines

Submarines are hard to detect when underwater and therefore very popular in the navies worldwide.

Types are:

- Ballistic Missile Nuclear submarine, large submarines (120-170 meters) armed with ballistic missiles. These vessels are part of the strategic nuclear deterrence force of the super powers. They can stay below the surface for months if necessary.
- Nuclear-powered Attack Submarine. Large submarines between 70 and 150 meters armed with:
- torpedoes, against surface vessels and submarines
- underwater-to-surface missiles (USM) against surface vessels
- cruise missiles against land-based targets
- General purpose Diesel-Electric Submarines. Small to medium submarines armed with torpedoes and USMs. The propulsion is provided by propellers that get their power from large batteries (accumulators). In order to recharge the batteries with their diesel generators submarines have to snorkel (submarine at periscope depth) at regular intervals.

2.4.7 Fast Attack Craft (FAC)

FACs have a displacement of less than 70 tons, a speed of 25 knots or more and are designed for fast hit and run tactics within a range of 100 miles from the coast.

2.4.8 Offshore Patrol Vessel (OPV)

Ships with a displacement of approx. 70 tons that can patrol the waters of the Exclusive Economic Zone (EEZ) for an extended period of time. Usually an OPV is lightly armed and equipped with a helicopter deck which enhances their patrolling capabilities.

2.4.9 Mine Counter Measure Vessels (MCMV)

An MCMV is any vessel that is designed to locate and destroy mines.

The main types are:

- Mine hunters. These vessels are equipped with several types of mine detecting sonars. They usually have a Remotely Operated Vehicle for investigation of a sonar contact and the delivery of an underwater destruction charge (mine).
- Fleet minesweeper. This type of vessel is capable of towing means to sweep anchored as well as bottom mines with acoustic, magnetic or pressure ignition.

2.4.10 Amphibious Ships.

Vessels designed to launch an amphibious force to a coastal operation area. Floating landing craft or helicopters are used for disembarkation of the force. There are many types of amphibious ships.

2.4.11 Landing craft.

Landing craft are smaller than amphibious craft, designed to sail towards a beach and allow vehicles, troops and equipment to leave the ship via a ramp at the bow of the ship. They are not designed to operate under rough conditions and are usually transported to the area of operation in an amphibious ship.

2.4.12 Support vessels

- Intelligence-gathering ships. A ship designed to gather information on other ships and coastal installations in other countries.
- Replenishment Oiler. This type of ship is designed to carry water, stores, fuel and ammunition and can supply these goods to other ships at sea, whilst underway.
- Hydrographic survey ship. A vessel used to survey the bottom of the sea to make charts for navigation.
- Oceanic Research Ship. This vessel gathers information about the physical and biological qualities of the sea.
- Rescue and Salvage Ship. Comparable to a seagoing tug, with equipment for fire fighting.

Trawler engaged in trawl fishing. Speed while fishing is approximately 3 knots, while not fishing, the speed can be 12 knots. The length of the nets can be between 60 and 80 meters and the lines can be 300 to 600 meters.

2.5 Fishing vessels

2.5.1 Trawlers

Trawlers are fishing vessels which drag their bag-shaped nets through the water. In pelagic fishery, the nets are suspended between the water surface and the seabed. In bottom fishery, the net is dragged over the seabed, which requires a high pulling power, especially if the nets are equipped with disturbing chains to churn up the sea floor. The construction and equipment of these fishing vessels strongly depend on the fishing method and the species of fish aimed at. The fish is kept on board during the fishing trip as refrigerated cargo.
The most important types of trawlers are the **derrick-cutter** and the **stern trawler**.

The derrick-cutter pulls its two nets, one on either side, from the ends of two derricks, which are fitted low, at the double foremast. Each net is kept open by a transverse beam, provided with sliding shoes and waking-up chains. The derricks are lowered as close to the water as possible during fishing, to prevent stability problems when one of the nets suddenly fills up with fish, or sand, or gets hooked at a wreck or suchlike.

The **stern trawler** has only one net, launched from a slipway at the stern. This net is kept open by two boards, one on either side shearing away, by the ship's speed. Stern-trawlers are usually larger than derrick trawlers.

Trawlers are like **tug-boats**. They have to pull the nets at relatively low speed over the seabed, which requires

Refrigerated trawler

enormous power especially at the end of a pull, when the net is full. These ships have diesel engines similar in power to a tugboat. The only difference is that the tugboat can be shorter in length with the same power, as it does not need space for cargo.
The propeller is built in a Kort-nozzle (see chapter 12), boosting the propeller-performance by some 25 to 30 %, and the bollard-pull accordingly.

Possible cargo

- cooled fish (in crushed ice)
- frozen fish or shell-fish

Characteristics

- engine power (bollard pull)
- volume of fish holds
- transport temperature
- freezing capacity
- method of fish processing
- method of refrigerating and chilling (cooling)
- the fish winch and net drum
- possible fishing methods

2.5.2 Other fishing vessels

Non-trawling vessels can range from a simple craft deploying crab / lobster baskets, a net or a long-line with floats and hooks, to fishing vessels which can lay out nets several kilometers in length, waiting for the fish to swim in. Typical examples are: seiners, tuna clippers, crab boats, etc.

Possible cargo

- frozen fish, or crustaceans
- cooled fish (in crushed ice)

Characteristics

- nature of the vessel
- fishing methods applied
- engine power
- refrigerating capacity
- volume of fish holds
- methods of processing and storing fish

Rainbowing

Trailing hopper suction dredger

Trailing hopper suction dredger,
length =167 meter,
breadth =31 meter,
carrying capacity =30000 tons

Split rail dredger

Cutter-suction dredger, rotating the entire barge with the cutter-suction beam(ladder) by the anchor-wires around its portside spud pole.

2.6 Dredgers

2.6.1 Trailing suction hopper dredger

Trailing hopper suction dredgers are used to maintain or deepen channels and fairways. These vessels are usually equipped with two adjustable suction pipes, which drag over the bottom sucking water with sand. Dredging pumps in the holds and / or in the suction pipes pump a mixture of water and material from the sea floor into the holds. They are able to dredge to a depth of 155 m. The holds are called **hoppers**. The solid material settles in the hopper; the excess water flows overboard. In order to dredge in waves, the suction pipes are suspended from special davits, which operate with heaving compensation to ensure that the suction nozzles stay in contact with the seabed.

When the vessel is at its (loadline) mark, it will navigate to the discharging site, either an area where the unwanted sand is just dumped, or to a location where sand is needed.

The discharge of the water/sand mixture can be done in two ways:

- If the ship can position itself at the exact destination, with sufficient water depth, the cargo is discharged by opening flaps or valves in the bottom. The cargo simply drops out.
- A second way of discharging is **rainbowing**. The bow of the ship is brought as close as possible to the dumping position and the water/sand mixture is pumped out through a bow jet to the desired position.

Some small hopper suction dredgers consist of two (port and starboard) halves, hinged at deck-level, which can be separated, opening the bottom over the entire length, where and when the cargo has to be discharged. These dredgers are called **split-rail suction** dredgers.

Possible cargo

- sand
- gravel
- stratum or clayish soil
- unwanted port sediment

Characteristics

- pump capacity
- depth range
- hold volume (the largest is 35,000 m^3, (2007))
- carrying capacity

2.6.2 Cutter suction dredgers

For tougher types of soils, the kind that cannot be simply sucked up like limestone etc., cutter suction dredgers are used. These vessels rake the seabed with a rotating **cutter** around the lower end of the suction pipe and are often used in the development of new ports and new waterways. Cutter suction dredgers are normally barges without propulsion, but a small number are equipped with their own means of propulsion.

Two **spud poles** are fitted at the rear end, with one lowered to pin-point the barge to the bottom. The other pole is pulled up. The dredger turns around the lowered spud pole pulling itself to port and starboard in a swinging motion from two anchors, laid out transversely from the forward end, while cutting and sucking the bottom material. By changing the spud pole one to another, at the end of each

Cutter-suction dredger with own propulsion. The spud poles are horizontally positioned to fore and can be lowered hydraulically when the ship is at the dredging position.

sideways turn, the dredger works its way forward. The soil/water mixture is usually pumped by the dredging pump via a floating transport pipeline to the destination, or pumped in barges alongside.

Characteristics
- torque and cutter power
- pump power
- presence of propulsion
- presence of transverse propellers
- length of the cutter arm and maximum working depth

2.7 Work-Ships

2.7.1 Cable laying ships.

Cable laying ships can lay one or more cables on the sea floor. If the distance exceeds the length of one cable, cables have to be joined together on board. These vessels are specially designed for this task. Apart from laying cables, the ships have the ability to repair a broken or damaged cable. Depending on the depth of the sea, and the possibility that fishermen have damaged the cable, the cable is dug in with by a plough and towed by the cable layer. Furthermore, during the joining of cables, the vessel must be able to keep its position. Crucial in the cable-laying process is that the positions of the cables on the sea floor correspond accurately to their positions on the map. Modern cable ships are therefore equipped with multiple adjustable, and often azimuthing, propellers in combination with DP and DT (dynamic positioning and tracking).

The cables are spirally stowed in large circular drums, whose diameter approximates the ship's width. The cable is pulled out from the center of the coil by the cable hanging behind the ship, at considerable speed.

Possible cargo
- new cables
- old cables
- repair equipment

Characteristics
- carrying capacity (ton)
- engine power
- details of DP/DT installation

2.7.2 Buoy positioners

Buoy positioner

A cable ship

Escort Tug

Tug assisting a VLCC

2.8 Auxiliary vessels

2.8.1 Tugs

– **Seagoing tugs**
Tugboats are relatively small, robust ships with a large pulling power. A common characteristic of all tugboats is their low aft deck. This is to provide the towing wire with some freedom of movement. The point of application of the force in the towing line must be located close to midships in such a way that the force has the least influence on maneuvrability. However, when the ship is on a long tow, the wire is secured sideways at the stern by a locking arrangement.
The wire adjustable in length, is stowed at a towing winch, positioned midships, usually with a double drum in order to have a spare wire in case of failure. The towing wire can be up to 1000 meters in length, with a diameter of 100 millimeters.
The main characteristic is the **bollard-pull**, the towing force at zero speed.

Seagoing tugs are used for:
- salvage
- towing
- anchor handling in the offshore industry
- environmental service
- assistance to ships with engine and/or steering problems
- fire fighting

Any floating object, like partly completed ships, floating wrecks, docks, drilling rigs and other large objects that have to be brought to a position at sea (or inland) can be towed by tugboats (if sufficiently sea-worthy)

Since the introduction of semi-submersible heavy lift carriers, long distance towing is used less often.

Coastal states often use seagoing tugs to avert an imminent environmental disaster.

Salvage means the saving of a ship, that otherwise would sink, ground, beach or burn out. Payment of the high costs of salvage is often a problem.

– **Escort tugs**
Escort tugs are used to escort (large) ships along dangerous passages. They were developed after a number of serious (tanker) accidents in recent years. Escort tugs operate in confined coastal waters and are small, sturdy, seagoing tugs that can push or pull a large ship away from a dangerous area when its own propulsion is not sufficient. Escort tugs need to be highly maneuvrable and therefore often have azimuthing thrusters.

– **Harbor tugs**
Harbor tugs are used in ports, inland waterways and coastal areas for:
- assisting and towing vessels in and out of ports
- assisting seagoing tugs when these are towing a bulky object in confined waters
- salvaging, or assisting in salvage in ports or coastal areas.
- fighting fires and environmental disasters.
- keeping ports free of fixed ice

Characteristics
- power installed
- bollard pull
- salvage pump capacity
- fire fighting equipment
- pollution fighting capability
- speed without connected object
- range and bunker capacity

2.8.2 Icebreakers

Icebreakers are similar to tugboats - great engine power in a relatively small ship and often fully equipped for towage and salvage.
Their main function is to cut a channel through an ice-layer at sea, in a port, a river or other (inland) waterways. Obviously these ships have to be able to resist floating ice. The fore-ship is especially reinforced and the steel used must have a very high impact value at low temperatures. The shell must be free of protrusions because floating ice will rip these off immediately. The bow often has nozzles connected with a pipe-system discharging compressed air, which can be blown under the ice-layer, breaking it upwards.

There is hardly a paint strong enough to resist the forces involved in ice-breaking. The wear resistance of the steel of the shell plating and the propeller is thus, subject to high requirements. Ice is usually broken by moving the sloping bow on to the ice, until the weight of the fore-ship breaks the ice. Some icebreakers have nuclear propulsion.

Characteristics
- engine power
- bollard pull
- shape of the fore-ship, is important for the method of icebreaking.
- total mass of the ship, important for the ability to penetrate the ice.

Cargo vessel with icebreaker stem

The same cargo vessel in ice

Icebreaker clearing a passageway for a freighter

2.8.3 Pilot boats

Entering into and departing from a port needs to be carried out safely. The ship's crew often has limited knowledge of local conditions.

Dangers, recent changes, customs and rules differ from port to port and can change continuously. Therefore local knowledge is hired.
Usually this is a pilot coming on board just before entering the particular port. That pilot can be boarded or debarked by:
- a tender (small fast boat) from the actual port,
- a pilot boat at station at sea, close to port, with small tenders
- a helicopter (often only for very large ships)

From shore, a ship can get directives about how to maneuvre from a so-called Vessel Traffic Service (VTS).
A VTS controls the shipping using a shore-radar system and radio communication.
A shore-based controller informs the ship's crew and/or the pilot about possible hazards and other traffic.

Characteristics:
- speed
- number of available seats and beds for pilots

Seaworthy sailing yacht, 27 meters

2.9 Yachts

Yachts can be divided into motor yachts and sailing yachts with or without an auxiliary motor. These vessels are purchased by:
- Private individuals for leisure use time; these yachts have a length of 10 to 20 meters.
  Wealthy persons who use the yacht as their (temporary) domicile, either for leisure or for business purposes.
- Companies that use the yachts for representative purposes; these yachts usually have a length of 15 meters or more.
- Private individuals or companies who buy the yacht for races.
- Large yachts used in chartering; the length of these yachts starts at approximately 15 meters.

The building of large luxurious yachts is very similar to the building of commercial ships, but with more emphasis on the finish and appearance.

Possible cargo
- owner and guests
- passengers

Characteristics
- total sail area and nature of the rigging
  motor power
- number of cabins and number of berths
- luxury
  seaworthiness

2.10 Fast Craft

2.10.1 Hovercraft

A ship can be much faster if the resistance of waves and friction can be considerably reduced or even eliminated.

A hovercraft is a platform which operates by "floating" above land or water on a self-created air cushion. There is no physical contact between platform and water, which reduces the friction enormously. Waves are nearly non-existent and friction between hull and air is only a fraction of the friction between a ship's shell plating and the water. The air cushion permits the platform to move in any direction. A high speed in forward direction can be reached using air-propellers and steering is done using air-rudders. The depth of the air cushion can be manipulated locally, also producing movement in the direction of the thinnest air layer.
An advantage is that these ships can move over water, land and ice, as long as it is reasonably flat.
Sizes differ from one-man-crew to a large crew and a few hundred passengers and cars.

Possible cargo
- passengers
- light cargo

Characteristics
- speed
- dimensions
- noise

Hovercraft

2.10.2 Catamaran.

A catamaran is a vessel with two hulls, each with a very large L/B ratio, creating a low wave resistance. The two hulls are connected with each other at deck level by a rectangular platform. The combination of the two hulls results in great stability, where a single hull would be unstable. The waterline area and displacement is low, restricting the cargo capacity. The result is a ship that can only carry light cargoes, like passengers over short distances in protected water between islands, in rivers, canals, river deltas etc.

Catamaran in dock

A variation is the **trimaran**, having three hulls, where the middle hull is bigger than the two outer ones. Its maximum length is 126 meters. Catamarans and trimaran vessels are also called multi-hull vessels.

On many inland waters regulations have come into force regarding maximal wave height produced by passing craft, protection of banks, dikes and people. Due to the slender hulls, catamarans can cope with these regulations more easily.

The term **"low wash ship"** has been introduced for catamarans producing waves with a maximal height of 0.5 meters. The maximum wave height a normal catamaran produces is approximately 1 meter.

Possible cargo
- passengers
- light cargo

Characteristics
- speed
- maximal wave height produced

Hydrofoil passes a feeder ship at high speed

2.11 Offshore equipment

2.11.1 Introduction to the Maritime Offshore Industry

As our world continues to expand in population and the total energy demand is ever growing, this makes us more than ever dependent on "energy".
Today oil and gas are still our most important sources of energy.

Within the world of oil and gas, crude oil is called **"Petroleum"**. Petroleum is a combination of the Greek word PETRA and the Latin word OLEUM. Petroleum literally means "ROCK OIL". Crude oil actually comes from rocks (the oil is entrapped within rock formations and the different layers of rocks). Most of the oil and gas is found within the so-called Sandstone and Limestone layers. According to scientists, oil and gas come from the remains of plants and (minuscule) animals that lived and died in the sea, millions of years ago. As time passed, large amounts of sediment covered the organic material. The increasing weight of these overlaying sediments resulted in tremendous pressure and heat on the organic material and transformed this material during millions of years into oil and gas. Parallel to this process the surrounding organic material transformed into sedimentary rock e.g. sand and limestone.

2.11.2 The early developments

In the early 1800s whale oil was used for illumination and lubricating purposes. Around the year 1850 this oil became very scarce and expensive as whales in the USA waters had been hunted to near extinction. As a consequence people were anxious to find alternatives.
Around this time an oil well near Titusville, Pennsylvania, was found where oil spontaneously came to the surface. It literally leaked out of the rocks which inspired a man named Colonel Drake to recover this "rock oil" and sell it as an inexpensive substitute for whale oil. Recovery of the oil by simply collecting it from trenches did not work out well. This finally - after some years of trial and error - resulted in 1859 in the early technique of drilling to collect the oil from its point of origin, initially at a depth of 21 meters.

In 1897, this was followed by extensive successful drilling on the beach and extended approximately 90 meters into the ocean from the coastline of South Carolina, the first steps to offshore activities!

Fifty years later the first **offshore oil** was found out of sight of land in the Gulf of Mexico, 9 miles offshore in a water depth of 6 meters. From then on over the last 50 years progress has been revolutionary. Offshore oil and gas developments are now taking place, hundreds of kilometers from the shore in ever-increasing water depths.

2.11.3 Definition of "Offshore"

The word "Offshore" in the Oil and Gas Industry refers to industrial activities in open sea, starting from the search (exploration) of oil and gas to production (exploitation) and transportation to shore.

The Offshore is part of an industry that actually designs, builds and operates the offshore structures to allow the execution of offshore activities.

2.11.4 Stages of Offshore activities

The table on the next page briefly highlights the main activities of the Offshore industry and of the vessels/ units in use to facilitate the availability of "Oil & Gas".

The order in which ships are described in the following pages and units, is in accordance with the sequence of development of production, from search to delivery, as follows:

- search
- evaluation of seismic information
- exploration drilling
- production drilling
- crane barge
- production platform
- FPSO / FSO
- shuttle Tanker or Pipeline

	Item	Activity	Vessel / unit in operation
a	searching for oil	seismic surveying	seismic survey vessels
b	finding it	– exploration	1. Jack-up drilling rigs, see note 1 2. Drilling vessels (ship shape), see n. 1 3. Semi-submersible drilling units
c	building the production facilities	– construction and installation of the production platform/unit	1. Crane vessels 2. Offshore barges 3. Heavy lift carrier
d	developing the field	- drilling and completing the production wells and interconnecting the production wells with the production facility	1. Jack-up drilling rigs 2. Semi-submersible drilling units 3. Pipe laying barges or pipe laying vessels
e	getting the hydrocarbons to the surface and processing at the surface	- production depressurization and separation into oil, gas and water fractions	1. Fixed platforms 2. Tension leg platforms 3. FPSOs (Floating Production Storage and Offloading Vessel) 4. FSOs (Floating Storage and Offloading Vessel) 5. Production jack-ups or semi-subs 6. Subsea installations 7. Others, see note 2
f	bringing 'the product' to shore	- transportation	1. Shuttle tankers 2. Pipelines, laid on the seabed by pipe laying vessels, see note 3
g	support	– supply and services – maintenance and repair - watch keeping	1. Suppliers, crew boats, anchor handlers 2. Diving and Multipurpose support vessels 3. Standby and chase vessels

Notes:

1. *The type of vessel / unit to be used depends on the water depth. Due to the limited length of the legs of the jack-up drilling rigs, these rigs are limited in their drilling operations to a maximum of 120 to 150 meters water depth; in general preferred because of their stable work platform.*
   Within and above the operational limitations of the jack-ups the semi-submersible drilling rigs may be used.
   Depending on the distance to the shore base and the expected sea conditions, the ship-shaped drilling vessel is a good alternative.

2. *The technique to get the hydrocarbons to the surface has been rapidly expanding over the last decades, resulting in all kinds of different types of production facilities such as:*
   - *SALM (Self Anchoring Leg Mooring system)*
   - *SALS (Self Anchoring Leg System)*
   - *Spar (A very large spar buoy with production and storage facility)*
   - *SPM (Single Point Mooring system)*
   - *Satellite Platform (Unmanned)*

3. *The technique of laying pipes on the seabed in extended water depth has drastically improved and as a consequence, more and more "high-tech" pipe laying units have been built and are successfully operating. To allow the installation of pipelines in open sea the following pipe laying vessels are used:*
   - *S-lay pipe laying vessels (shallow and deep water)*
   - *J-lay pipe laying vessels (deep water)*
   - *Reel-lay pipe laying vessels (small diameter).*

Technical aspects

All the technical aspects, such as strength, stability, hydro-dynamical behaviour, freeboard, safety etc., in the design and engineering process of ordinary ships are also applicable to offshore craft augmented by the specific technical requirements within the offshore application.

Certification aspects

Based on the applicable specific tasks, Classification Societies and National Authorities have imposed additional Rules, Regulations and Requirements as a basis for certification and safe working conditions.
See also chapter 6.

Seismic survey vessel in dry dock

Seismic survey vessel in operation

2.11.5 Brief description of offshore units.

a. Seismic Survey vessel

The purpose of a Seismic Survey Vessel is to produce detailed information for oil companies as a basis for actual production drilling.

This information is the result of the evaluation of the reflected sound waves in the sea floor. To obtain these results sound waves are initiated by a vessel by means of air guns; the reflections are collected by a number of detectors within long cables (so-called streamers) towed by the survey vessel.

b.1 Jack-Ups

The Jack-Up drilling rig is used for **exploration drilling** from approx. 10 meters to max. 150 meters water depth. The **Jack-Up barge** is a triangle or rectangle-shaped barge which is towed to the work location. At the location the barge lowers its legs till they are on the seabed and afterwards climbs into the legs, lifting itself to a working height, safe above the waves.

Jack-Up Barges are mainly used for exploration drilling (usually 3 legged) and as a work barge for construction work (typically 4-legged). Long distance transport of Jack-ups is by towing with a tug (wet tow) or by heavy-lift transport ship.

Jack-up rig in drilling mode, suitable for arctic conditions

1. Derrick
2. Cantilever
3. Helideck
4. Jackup System House
5. Pipe storage
6. Drill floor and wind wall
7. Leg
8. Deck cranes
9. Deck house or accommodation
10. Monkey platform
11. Deck, tanks and work spaces
12. Chase vessel

Jack-up rig in a jacked up position.

Drilling ship

1. Drilling derrick
2. Drill floor
3. Riser and pipe storage
4. Supply handling crane
5. Accommodation / helideck / lifeboat stations

b.2 Drilling Ship

A ship-shaped drilling unit used for drilling, exploration and production wells in medium to deep water (from 150 to 3000 meter water depth).

A modern drill ship can obtain an average speed of 14 knots in transit with a high drilling equipment storage capacity. The vessel is ideal for drilling consecutive wells in different parts of the world.

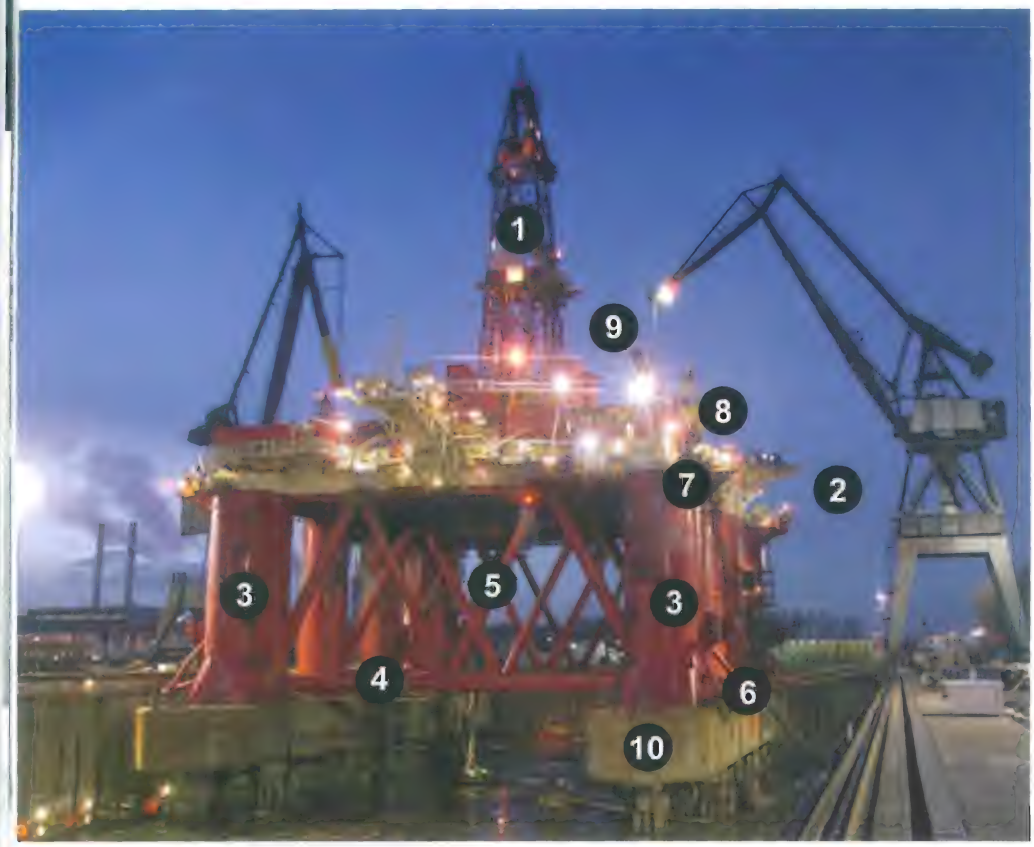
To maintain position during drilling operations the ships are either anchor moored with 8 or 12 anchors on long wires and chain, or rely on Dynamic Positioning (DP), depending on the water depth.

b.3 Semi-Submersible Drilling Unit

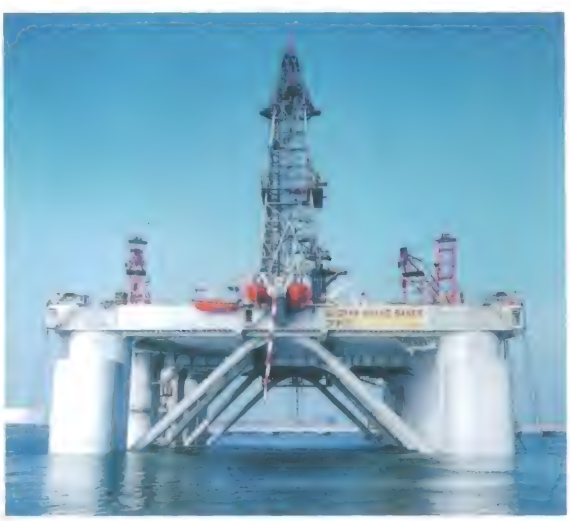
A semi-submersible drilling unit is used for drilling the exploration and production wells in 150 - 2,500 meter water depth.

Anchored units can operate in up to 1,500 meter water depth. Dynamically positioned vessels can operate independent of water depth (up to around the year 2000 drilling was performed in up to 2,300 meter water depth).

An important advantage of the Semi-submersible type is the improved motion behaviour of the platform in harsh environments, which gives a larger working window



Semi-submersible drilling unit in drydock



1. Drilling derrick
2. Deck
3. Columns
4. Cross brace
5. Diagonal brace
6. Anchor racks
7. Anchor winches (on corner edges)
8. Lifeboat station
9. Deck cranes
10. Floater

Semi submersible at operational draught

A dynamically positioned (D.P.) vessel uses its propellers, rudders, tunnel thrusters and/or azimuthing thrusters to stay on position.
A control system continuously determines the required thrust vector based on information from a position reference system, like radio or hydro-acoustic beacons or GPS.

c.1 Crane Vessels

These are ship-shape and semi-submersible barges or vessels, equipped with one or two heavy-duty offshore cranes. The largest crane vessels are the Semi-Submersible Crane Vessels (SSCV). The maximum hoisting capacity is 7,000 tons per crane, with two cranes on one barge. The crane-vessels are used for lifting and installation of large modules (weighing up to 12,000 tons) for fixed offshore platforms, from transport barges onto the fixed platform.

Recently crane vessels are coming into use for the removal of offshore platforms when the oil/gas reservoirs are depleted. Some crane vessels also have pipe laying facilities.

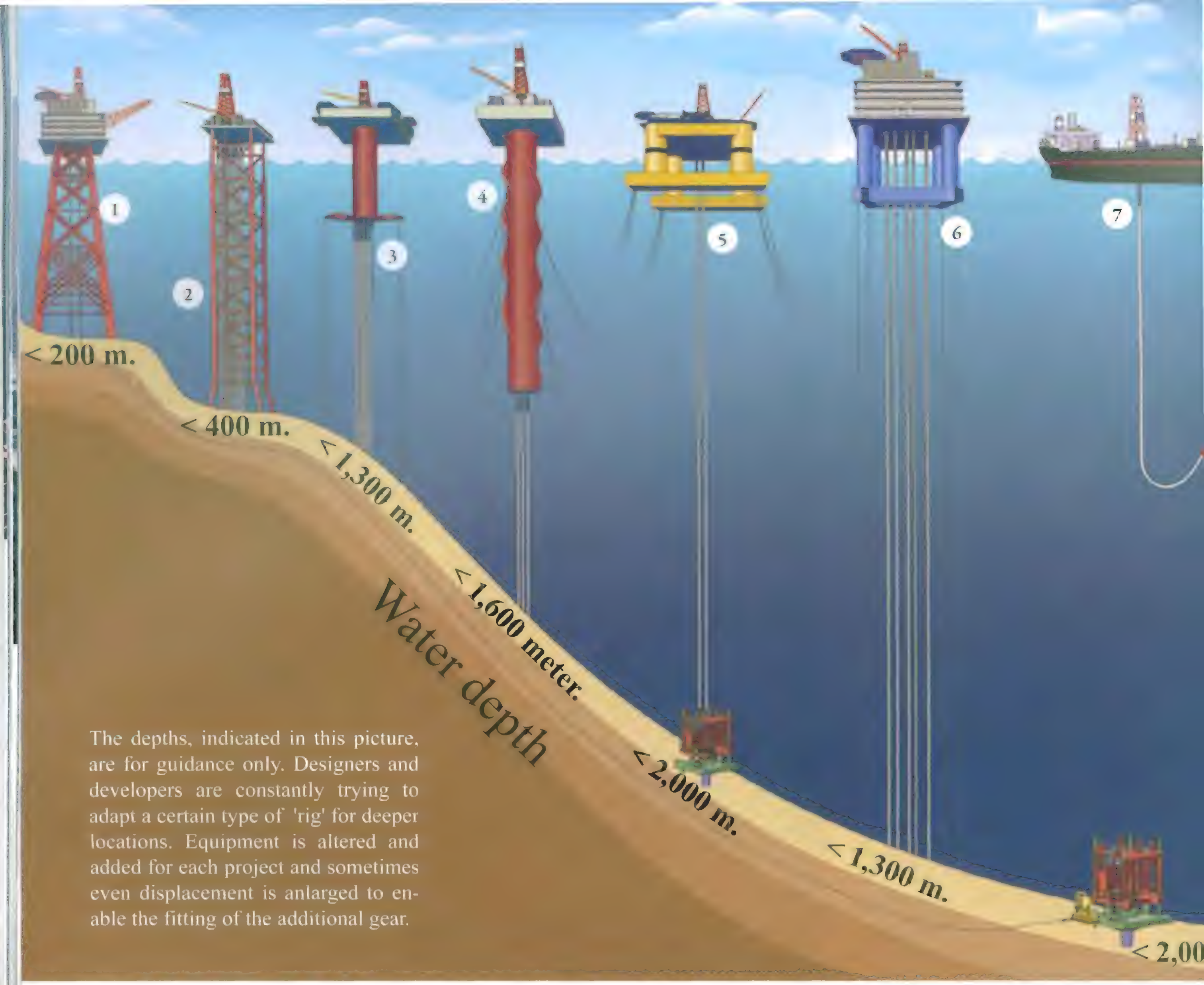
1. J-lay tower
2. 3,000 ton crane
3. 4,000 ton crane
4. Crane A-frame
5. Fly-Jib
6. Storage barge
7. Tugboat
8. Accommodation / helideck / lifeboat stations
9. Pipe storage rack

Dual purpose semi-submersible crane vessel for heavy lifting/installation and (J-lay) pipe laying

The base of the platform (called jacket) is either launched from a barge or lifted onto the sea-bed by the crane vessel prior to installation of the topside modules. After installation of the jacket it is firmly connected to the seabed by steel piles, that are driven down by large hydraulic hammers suspended from the offshore cranes.

Crane vessel installing fixed platforms

Module:
On top of a jacket, various items are to be fitted and interconnected. These parts are pre-fabricated as much practicable, and as squarely as possible, so that when placed on top of the jacket, and after fixing them permanently to the structure of the jacket, only connections between these items have to be made. These pre-fabricated structures, often box-shaped are called MODULES. The weight of each module is limited by the weight the available offshore crane unit can handle.



1. Fixed Platform, jacket type. (deepest water depth 412 meter.)
2. Fixed Platform, Compliant Tower type (deepest water depth 535 m.)
3. Floating Platform, Mono Column TLP type (deepest water depth 1,311 m.)
4. Floating Platform, SPAR type (deepest water depth. 535 meter.)
5. Floating Platform, Semi-sub type (deepest water depth 2,000 meter)
6. Floating Platform, Four Column TLP type (deepest water depth 1,432 m.)
7. Single Well Oil Production Systems (SWOPS) (deepest water depth 1,852 meter)

Various types of offshore structures (fixed and offshore floating structures

e.1 Fixed Production Platforms

Production Platforms are onshore prefabricated structures, providing a working platform for production drilling, production and the starting point of a pipeline to the collecting unit.

After construction ashore the platform is transported lying on its side on a barge to the production location at sea and launched from the barge into a vertical position on the seabed. Afterwards it is nailed to the seabed by piles, with the help of a floating offshore crane. Modules are afterwards lifted onto the platform, and interconnected.

A drilling derrick and a flare boom are installed.

After commissioning the drilling can start. After installing well-heads with the necessary pipeline connections, the production can start.

The platform can be subdivided into the following main components:

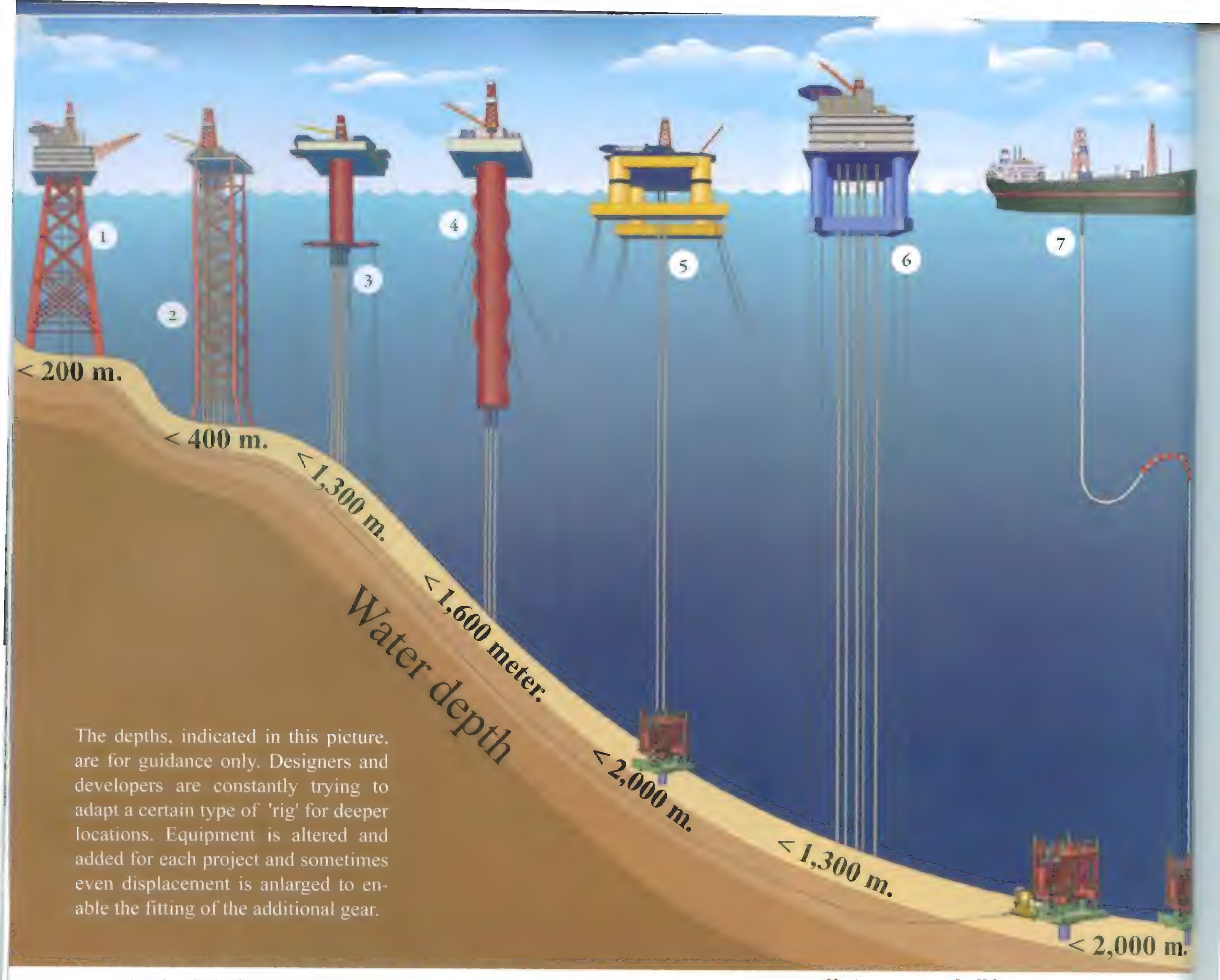
steel jacket or concrete substructure deck
- modules
- drilling derrick
- helideck
- flare boom

Most platforms stand in water depths varying from approx. 20 m. to 150 m.

The highest jacket built so far was for a water depth of 412 meters.

e.2 Tension Leg Platform (TLP)

The Tension Leg Platform is used for drilling and production purposes. The unit resembles a semi-submersible drilling unit and is attached to the sea floor with vertically tensioned steel cables. The buoyancy of the platform applies tension to the cables. The advantage of the TLP is its economical aspect in comparison with the fixed platforms, specifically for deeper water. In case the production in a particular field ends, this type of platform can be moved to other locations.



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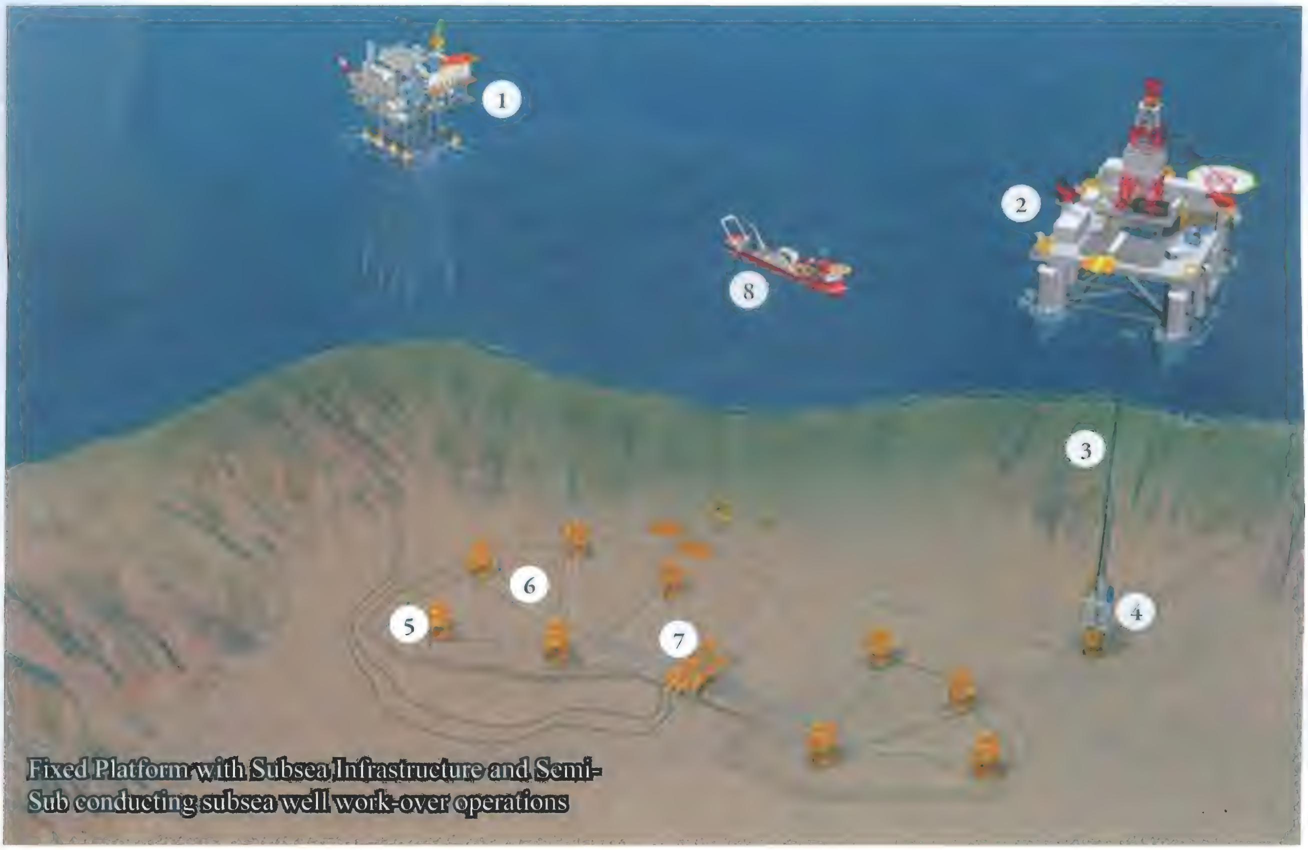
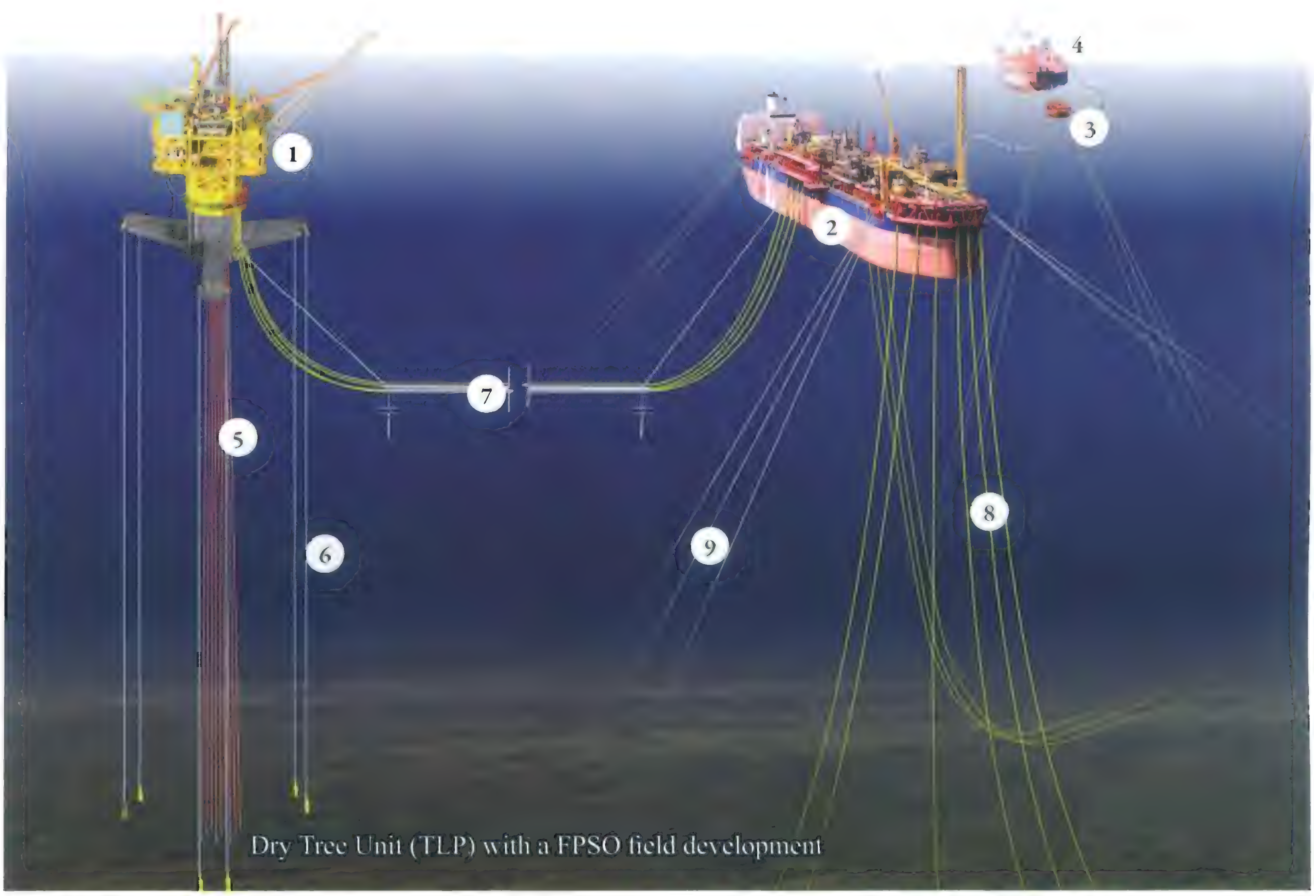
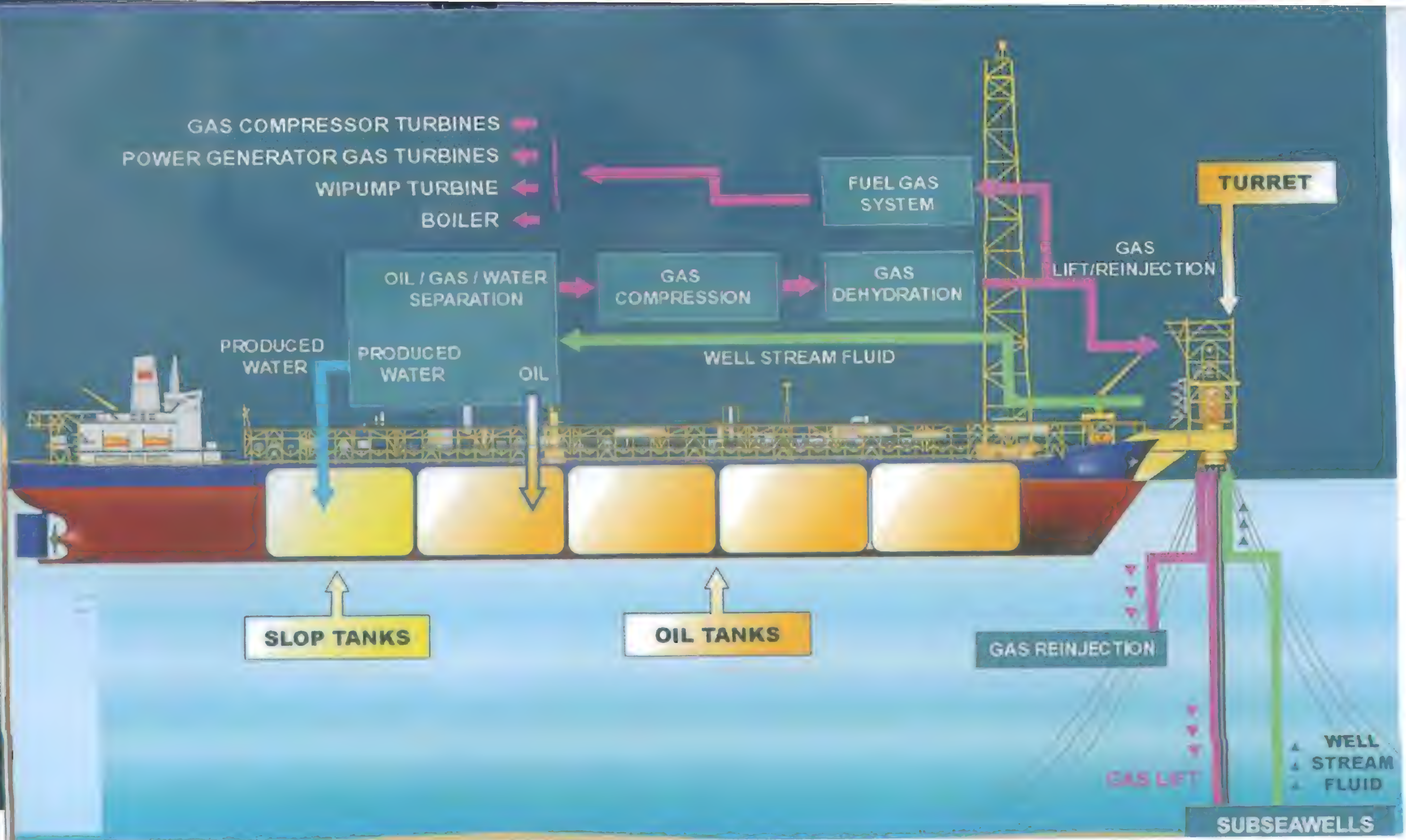


1. Fixed Platform
2. Semi Submersible Drilling Unit
3. Marine Drilling Riser
4. Blow Out Preventer (BOP)
5. Subsea wellhead and X-mas tree
6. In-field flow lines
7. Pipeline End Manifold (PLEM)
8. Diving Support Vessel (DSV)
9. Catenary mooring lines



1. Dry Tree Unit (TLP)
2. FPSO
3. Calm buoy
4. Shuttle Tanker
5. Risers
6. Tendons (taught mooring lines)
7. Gravity Actuated Pipe (GAP), export line
8. Flowlines
9. Catenary mooring lines



Schematic view of the process and storage on board an FPSO with an external turret

e.3 Floating Production Storage and Offloading (FPSO) vessel.

A FPSO vessel produces crude oil from fluids pumped up from the oil wells. On the vessel the fluids are processed to separate the crude oil from water and the gas and oil are temporarily stored on board until the oil is offloaded to a shuttle tanker.
The DP-FPSO is a recent development whereby the FPSO is kept on position by means of a Dynamic Positioning (DP) system using azimuthing thrusters. Conventionally an FPSO is kept on position by a spread anchor mooring system. In deep water an anchor mooring system is no longer feasible. The FPSO vessel weathervanes around the turret to keep the drift forces and the roll motion as small as possible by turning its bow into the waves. The turret is a vertical tube, going through the ship, from above deck to below the flatbottom, around which the whole FPSO can turn freely.
The flexible pipelines (called risers) that bring the fluid to the surface are connected to the turret from below. The oil is produced from several oil wells in the field and transported to the risers by in-field pipelines. Oil wells are drilled by a drilling vessel like the dynamically positioned drill ship shown here.

FPSO with shuttle tanker behind (the numbers are explained on top of the right page)

1. Flare stack
2. Proces equipment
3. Heli deck
4. Shuttle tanker

1. Bow loading station including temporary mooring arrangement to FPSO
2. Cargo lines
3. Heli-deck
4. Accommodation
5. Tanks below deck

Shuttle tanker in dry dock

f.1 Shuttle tankers

In the absence of a pipeline from the production facility to the shore terminal a shuttle tanker can be used to load the oil from the FPSO or FSO and transport this as cargo to the shore terminal. The shuttle tanker comes in position behind the stern of the FPSO and connects to a special adapter in the bow, the bow-coupler, by a hose. The Shuttle tanker can be connected with mooring lines from the FPSO, keeping its engine in astern mode to stay free from FPSO, but most shuttle-tankers today are dynamically positioned, without connection apart from the hose.

f.2 Pipe laying barges / semi-subs / vessels

For the installation of sub-sea oil and gas pipelines various barges and vessels are used:

- anchor-moored or dynamically positioned flat bottom barges, semi-submersibles
- ship-shaped vessels

Many of these pipe laying vessels also have a heavy-duty crane for construction and/or installation work.

On the main deck of the barge or ship, the pipe pieces (joints) are welded together. For this purpose a complete pipe joining/welding and coating factory is installed on deck. After welding the pipe joints, non-destructive testing (NDT) is carried out before the pipe is, moved aft, length by length, horizontally, over the so-called firing line via the pipe stinger

The stinger is a guidance beam, preventing the pipe from buckling

Combined Reel-Lay and J-Lay pipe laying vessel

1. J-lay tower / Reeling ramp
2. Storage reels for flexibles / rigid reeled pipe line
3. Pipe rack for rigid pipe sections
4. Board crane 400 ton capacity
5. Accommodation / heli-deck / lifeboat station

directly behind the barge, guiding the pipeline into the water, and to the seabed. The stinger extends outboard over the stern of the pipe laying barge and functions as an articulated outrigger that allows for the lowering of the pipe line onto the seabed. This process is controlled by means of pipe tensioners (varying in capacity from 40-250 tons), taking the weight of the hanging pipe and allowing some movement due to waves, etc.

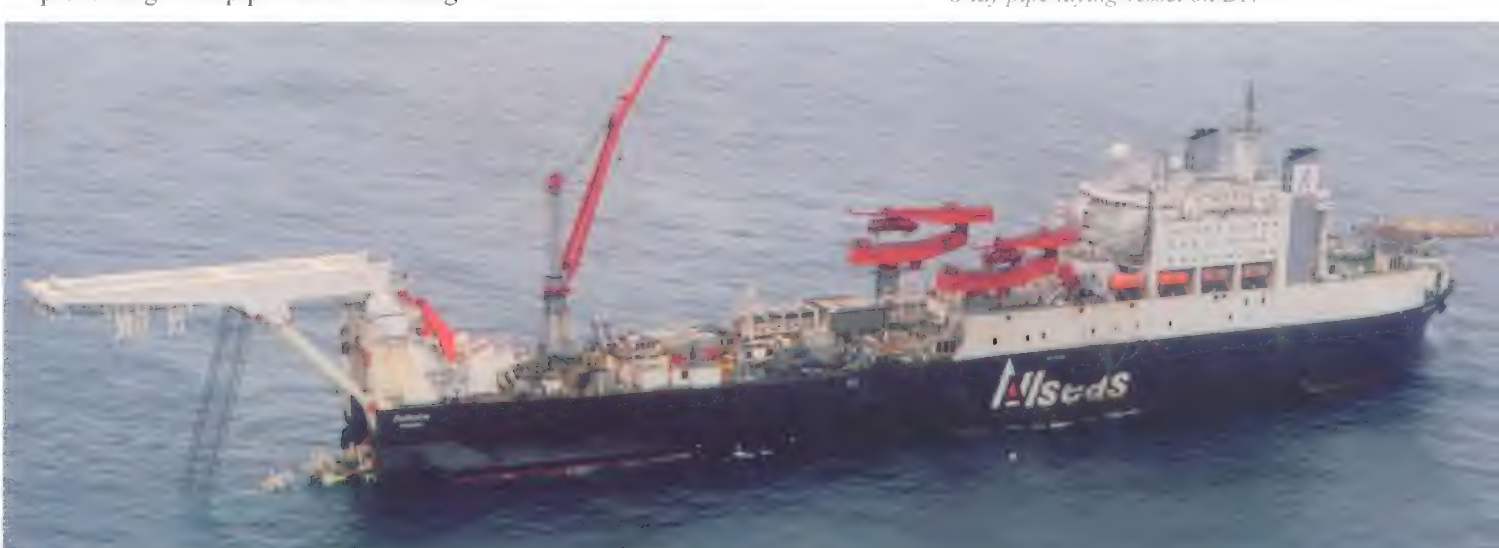
Pipes are supplied to the pipe laying vessel by PSV's or by pipe-supply carriers, multi-purpose ships, where the pipes are on board as cargo. They moor alongside the pipe layer, at sea, open their hatch, and the pipes are discharged from the cargo-hold, with cranes of the pipe laying vessel which hoist the joints into temporary pipe storage racks.

Welding the pipe pieces together and transporting them aft via the stinger to the seabed is called **S-lay**.

S-lay is used widely up to 1000 meter water depth. New inventions using a long stinger which guides the pipe in a vertical direction at the end of the stinger allow S-lay in 3000 meter water depth and beyond.

For deep water (over 1000 meter water depth) installation of sub-sea pipelines a **J-lay** tower is commonly used. This J-lay tower is installed vertically and allows welding, coating, NDT and lowering in a vertical manner. The shape of the pipe when lowered onto the seabed resembles a hockey stick (hence the designation J-lay). Small diameter pipelines can be spooled on a reel at a shore base and are subsequently unreeled at their destination.

S-lay pipe laying vessel on DP.



Platform Supply Vessel

g.1a Platform Supply Vessel (PSV)
Supply vessels combine many functions and are used for the supply of fuel, drilling mud, fresh water, (drilling) equipment and pipes to or from offshore platforms or other vessels (e.g. supply of pipes to pipe laying vessels). During these supply operations DP is often used to stay in position. Another function besides supply, is fire fighting.
.Suppliers are characterized by a superstructure and deck-house forward and a long flat aft deck. They have no helideck and no cranes. The offshore platform or vessel uses its own cranes to lift cargo from the PSV deck.
The difference with an AHT is that a PSV has a long aft deck and below-deck storage tanks.

g.1b Anchor Handling Tug (AHT)
An anchor handling tug is used to set and retrieve anchors of moored offshore units and for towing these units. The AHT often looks similar to a PSV, but has a shorter aft deck and an open stern with a stern roll and large winches to be able to pull anchors on the deck. If the anchor handler can also function as a supplier it is called an Anchor Handling Tug Supplier (AHTS).
(see illustration chapter 1, section 6)

g.2a Diving Support Vessel (DSV)
Diving support vessels are used to support divers doing inspections, construction or repair work on sub-sea structures.
To facilitate the diving operations DSVs have diving bell(s) and decompression chambers for the divers.
A **moon pool** (a hole in the middle of the ship, allowing vertical transport of diving equipment) is used to lower divers or sub-sea tools.

Such a sub-sea tool is the Remotely Operated Vehicle (ROV), a self-propelled underwater remote controlled robot for inspection or construction and repair work. Usually the ROV is connected by an **umbilical cord** (a cable for power and controls) to the support vessel.

DSVs are anchor moored or dynamically positioned. When working with divers, very strict requirements to the anchor mooring or DP system apply, as a drift-off of the DSV could put the divers in danger.
Therefore DSVs have to comply with the highest DP standards (class 3).

g.2b Multipurpose Support Vessel (MSV)
A MSV is somewhat similar to a diving support vessel, but has no facilities for divers. Without diving operations, the DP requirements are less stringent.

MSVs can be used for a large variety of tasks like:
- survey work (e.g. seabed, pipeline, sub-sea structure);
  (sub-sea) construction, installation and maintenance or repair work;
- trenching of cables or pipelines;
- installation of flexibles;
- well intervention and workover services.

MSVs typically have a relatively large accommodation, a helideck, a flat work-deck aft, (heave-compensated) crane(s) and/or an A-frame aft and moon pool(s) for controlled lowering of ROVs or other equipment. The vessel can be ship-shaped or of the semi-submersible type. Often an MSV also has facilities for divers and can work as a DSV.

g.3 Crew boat
Used for crew changes of drilling rigs or other craft in benign waters. They are fast boats of approx. 20 meters in length, with an accommodation for some 24 passengers in chairs, and an open aft deck to take some spares. The crewmembers embark or disembark using a crew-basket, suspended from the crane of the rig or ship. In some areas (e.g. North Sea) helicopters are used for crew changes.

g.4 Standby vessels and chase vessels
Standby vessels stay in the neighborhood of platforms or offshore operations to perform rescue operations in case of emergencies. Chase vessels are used to chase ships away from platforms, offshore operations or seismic survey vessels and for supply operations. Of course these tasks can be combined in one ship. Often converted fishing vessels are used for this.

Chase Vessel

Weathervaning is the behaviour, deliberate or not, of a ship, when moored from a single anchor or mooring line, to position itself in the direction of the resultant of wind, waves and current so that the energy needed to stay in that position is minimised. For DP ships this influences the fuel consumption.

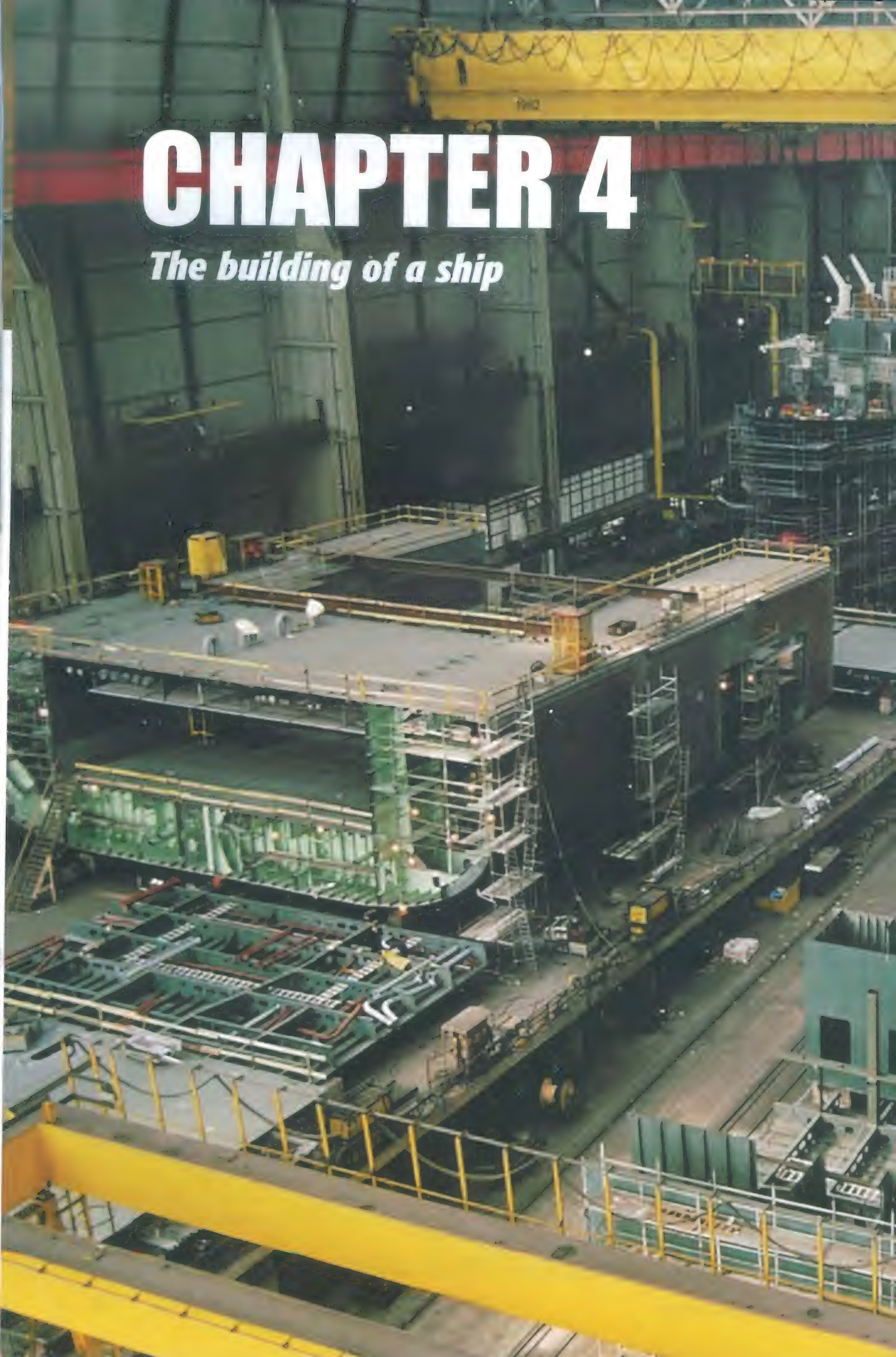
FPSO converted from a VLCC in Singapore ready for sail to Brasil.
L.o.a x Br. x T: 343 m. x 52 x 21 meter.
Crude storage capacity: 1,600,000 barrels (= approx. 252,800 m^3)

1. Internal Turret (Pivot point)
2. Flare tower (100 meter high)
3. Gas lift compression modules
4. Crude separation modules
5. Power generation modules
6. Water Injection Treatment Module

Side-by-Side offloading of worlds first new-build LPG FPSO offshore West Africa.
L.o.a x Br. x T: 263 m. x 49 x 13,2 meter. Gas storage capacity: 135,000 m^3

CHAPTER 4

The building of a ship



1. Pre-contractual work

Prior to the signing of the contract between shipyard and ship owner for the actual construction of the ship, the shipping company, financer and future owners have already completed a long road of negotiations and considerations. Unlike a car, most cargo ships are not ready for delivery in a wide range of pre-constructed models. Most new ships are designed and constructed following the specific requirements of the shipping company. However, more and more ships are built in larger series on a **standard design**, with limited variations between different ships. This makes series-production possible, enabling a shipyard to increase its production efficiency

The advantages of a standardized ship are:

- the clients know what they can expect
- the design has already proven itself and can be optimized during the series
- the price and construction are known
- the almost complete absence of the design and engineering period shortens the delivery period of later ships in the series
- the costs for design and engineering of the ship are spread over multiple ships, so the overall costs per ship are lower.

The disadvantages of a standardized ship are:

- the design may not be entirely suitable for the requirements of the shipping company
- the involvement of the shipping company is limited to details only
- more competitors may operate the same ships, which are not optimized for a particular trade or shipping company.

In spite of the disadvantages, shipyards have introduced good and versatile standardised ships in recent years. Some shipping companies are now ordering whole series of these ships with sometimes only a few modifications to the design. However, each modification costs extra.

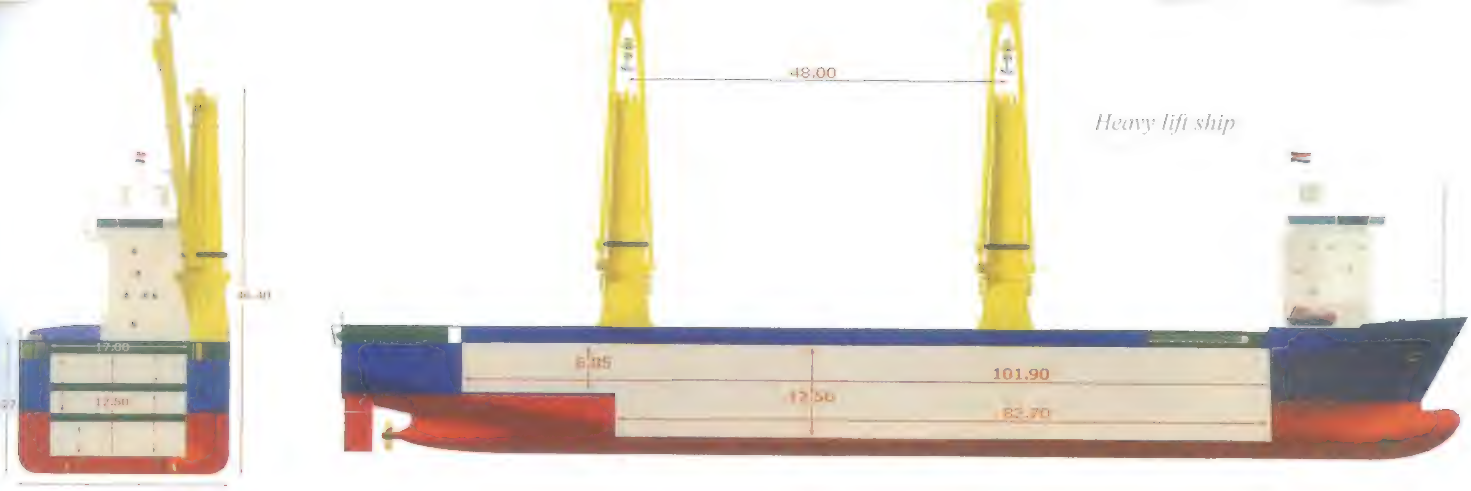
1.1 Owners' requirements

Most shipping companies first define formal owners requirements, in particular if the ship will be newly designed and optimized for the shipping company.

Navigation equipment

It specifies several characteristics of the new ship, such as:

- the desired carrying capacity and tonnage
- desired service speed and trial speed
- types of cargo the ship must be able to transport
- cargo-hold lay-out
- system of hatches/hatch covers
- necessity, capacity , Safe Working Load and type of cargo gear
- preferred suppliers of the engines, auxiliaries, navigation equipment, cargo gear etc.
- number of crew and passengers to determine the number of cabins
- composition of the crew, luxury and dimensions of the cabins and general accommodation
- operational area
- operational range to determine the size of the fuel tanks and storage compartments
- limitations to the size of the ship in respect to the routes it will navigate (bridges, locks, water depth etc.)
- special requirements like strengthening for navigation in ice (ice class) or ramps in the side of the ship
- if freight contracts have already been made, the ultimate completion date
- required certification, classification society and flag of registration.



Heavy lift ship

The shipping company then submits this list of requirements as a call for tenders to several shipyards. The shipyards will then inform the shipping company if they are interested in preparing a **tender** for design and construction of the required ship(s).
This may depend on:

- the technical capability of the shipyard and experience with the ship type
- the capacity and earliest delivery time that the shipyard can offer
- the amount of material and manpower that is required in the available time
- special interest of the shipyard to build such a type of ship?
- expected price level
- expected competition

After informative talks the shipping company sets a time period in which the shipyards can submit an offer (tender, quotation) without engagement. This means that the shipping company does not have to pay for the offer and that the shipyards do not know which one will get the contract.
Sometimes the shipping company already has a preference for a particular shipyard, and then the offers are used in the negotiations with the preferred yard.

Pontoon hatches used as tweendeck in a multi purpose ship

1.2 The preliminary sketch

The offer without engagement is the response of the shipyard to the invitation to tender. This offer consists of a preliminary design, which, in turn, consists of an outline specification, a preliminary General Arrangement plan and an estimate of the price . The **outline specification** is a brief technical description and the General Arrangement plan is a side and a top view of the ship, which shows the arrangement of the relevant spaces in the vessel. On the basis of a comparison of the offers, a shipping company will continue negotiations with 2 or 3 shipyards.
The Preliminary design for the tender is prepared in the project department (or Design department) of the shipyard. This requires a lot of calculations and design work, especially if the design is entirely new.

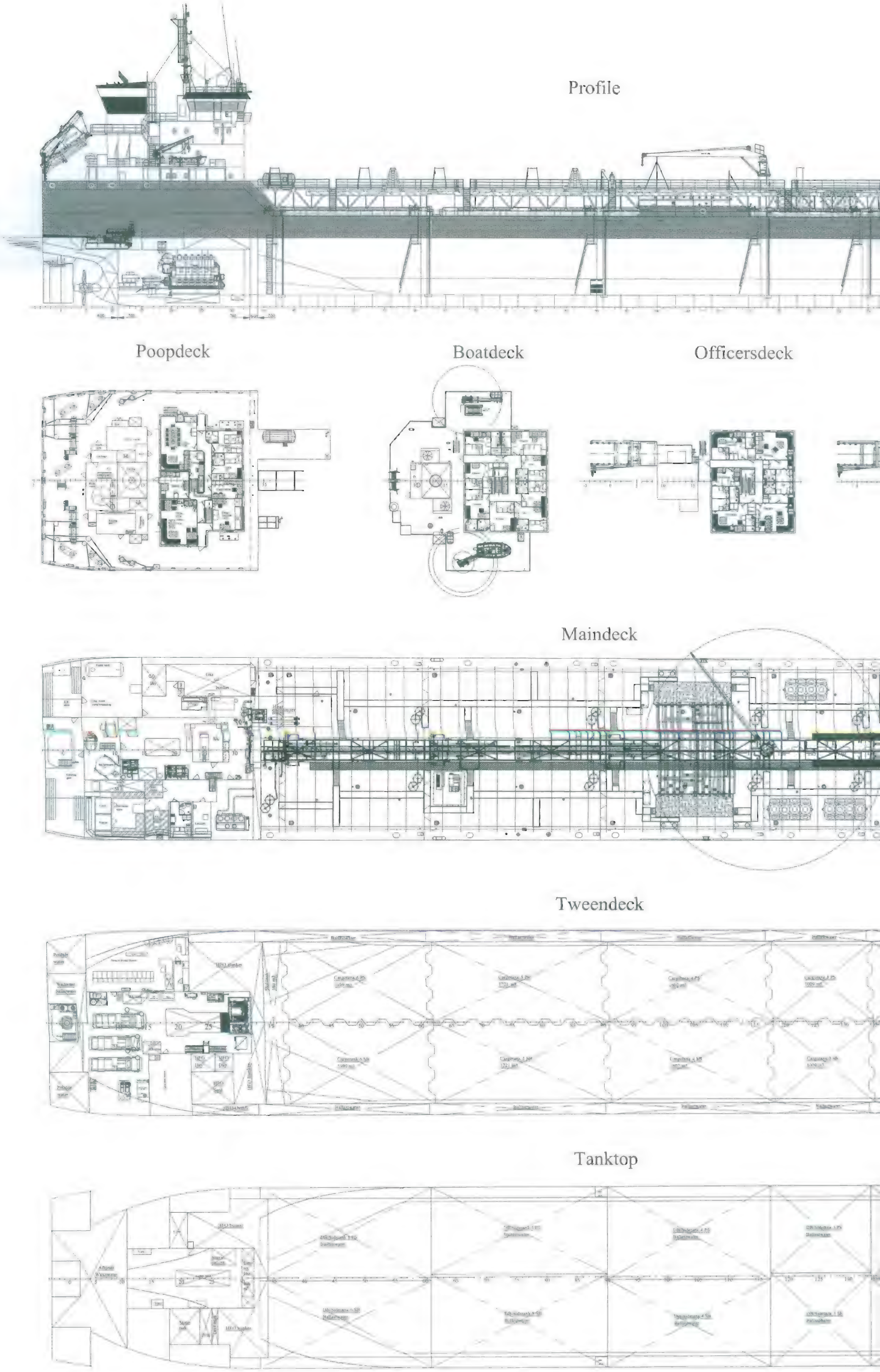
The vessel including its hull, machinery and equipment to be built under the special survey of Lloyd's Register of Shipping and to be classed and registered as +100 A1 +LMC, UMS, IWS, PCWBT, SCM, LA, NAV I, Iceclass 1A 'Strengthened for heavy cargoes' Timber deck Cargoes. Container cargoes in hold and on upperdeck', strengthened for regular discharge by grabs.

The vessel to be registered under the flag of the Netherlands.

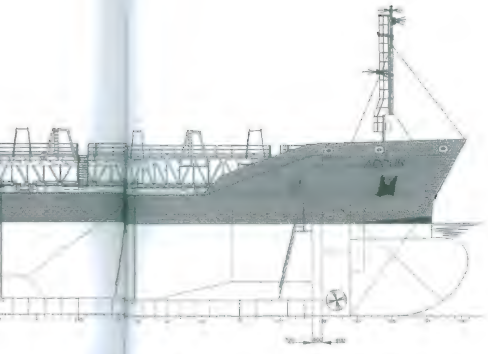
The following maritime Rules and Regulations, those coming into effect as of the date of execution of the contract to be complied with, including rules and regulations known at the day of execution of the contract, coming into force and being applicable to the vessel before actual delivery:

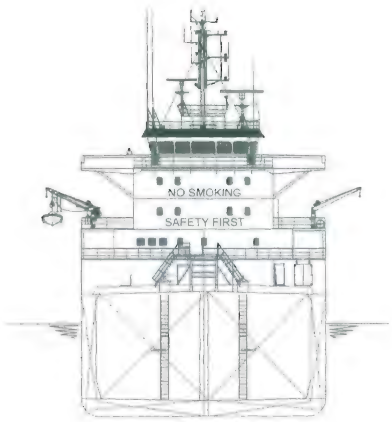
Rules and regulation of Classification Society
International convention for the safety of life at sea, 1992 and latest amendments
International convention on load lines, 1966
Regulations for the Measurement of Vessel (London, 1969)
Convention on the International Regulations for preventing collisions at sea, 1972
Convention on the International Regulations for preventing pollutions at sea 1973, 1978 (Annex I, IV, V) and latest amendments
Acts of International Telecommunication and Radio Conference (GMDSS Area III)
Suez Canal navigation rule
Panama Canal navigation rule
USCG rules for foreign flag ship visiting US harbour (+ USDPH)
Maritime rules of the Netherlands (NSI), including NSI Noise Regulations
Regulations of Unattended Machinery Space by NSI
Rule of Australian Waterside Worker's Federation (AWWF), Australian Navigation and Pilot Rule
Reg-54 of Solas 1981 for the carriage of dangerous goods DHI (Partial application)
St. Lawrence Seaway and Great Lakes requirements

Legal part of new building specification

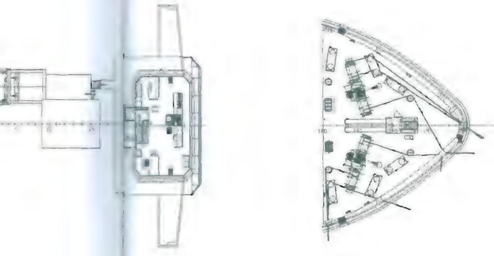


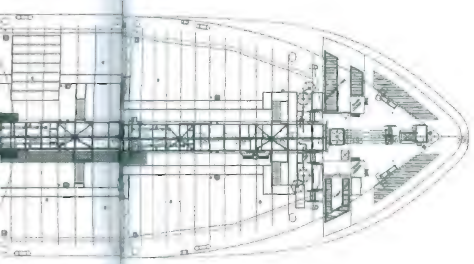
A general arrangement plan for an oil / gas / chemical tanker

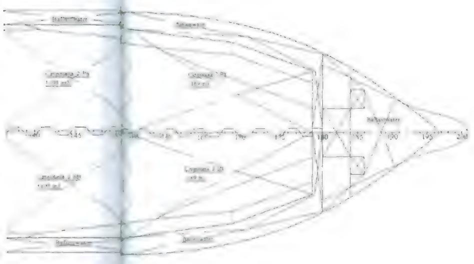


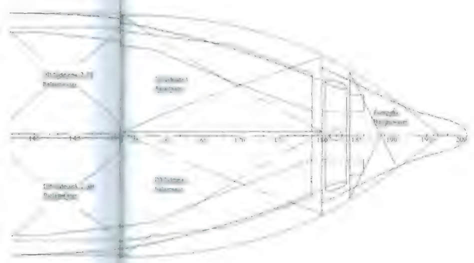


Bridgedeck Forecastledeck









PRINCIPAL PARTICULARS

Length o.a.	139.95 M
Length p.p.	134.70 M
Rule lenght Bur.Ver.	132.31 M
Breadth moulded	21.00 M
Depth moulded	10.60 M
Draft summer freeboard	CA. 8.06 M
Design Draft	6.90 M
Deadweight (6.90mtr)	appr. 11700 ton
Deadweight (8.06 mtr)	appr. 14800 ton
Draft scantling	8.10 M
Total engine output	5400kW
Service speed	14 Kn
Gross tonnage	approx. 8550 GT

CAPACITIES

Cargotanks 100%	appr.	16000 m3
Slobtank	appr.	380 m3
Washwater / ballast tank	appr.	247 m3
Ballast water	appr.	6014 m3
Potable water	appr.	99 m3
HFO	appr.	725 m3
Gasoil	appr.	114 m3

CLASS: BUREAU VERITAS

CLASS 1

✠ OIL TANKER / CHEMICAL TANKER

IMO II, Unrestricted Navigation

(association with a list of defined chemical cargoes, sailing under French flag)

✠ AUT-PORT

✠ AUT-UMS

✠ MACH

✠ BOILERS

✠ Hull

ESP, SYS-NEQ-1, IG, AVM-APS, MANOVR.

PETRO MARINE

26 Rue de CAMPILLEAU 33520 BRUGES (FRANCE)

Tel: (33)56 16 15 14 / Fax: (33) 56 57 64 74 / Telex: 560828 Petro

GEKEURD	aantal bladen	blad nr.	SCHAAL 200	GETEKEND 31-03-01 GDGD
	1	1	MAATEENHEID mm	GEZIEN

General Arrangement A0

Niestern Sander bv

BOUWNUMMER 814

TEKENINGNUMMER 1000

MEMBER OF CONOSHIP INTERNATIONAL

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9930 AC DELFZIJL
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Telefoon 0596-617979
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AUTEURSRECHTEN VOORBEHOUDEN
CAD-TEKENING, GEEN HANDMATIGE WIJZIGINGEN

A section on a screen

The demands on naval architects, Computer Aided Design (CAD) programs and designers are quite heavy and if the shipyard is too small to carry out such design and calculation work in a short period, they may co-operate with other shipyards, or subcontract the work to specialized design offices.

Various CAD computer-programs are used for the following activities (first in the preliminary design and later on in the final design):

- The **design** and optimization of the hull form, general arrangement of hull, decks and superstructures, maximum deck load etc.
- Hydrostatic calculations, both for trim and stability of the ship in various loading conditions and for checking stability in case of damage to determine the chance of survival. This stability has to fulfill the requirements of the IMO. Additionally the longitudinal strength of the ship is checked for the same conditions.
- Hydrodynamic calculations, calculations that are performed to estimate the resistance of the ship, and to determine the characteristics of the ship's propeller and its propulsive efficiency, from which the power to be installed can be derived. From these calculations the 'speed – power curves' are derived. In these curves the required engine power is plotted against a certain speed, usually for 'trial and service conditions' (smooth sea, new clean hull, no wind with a certain 'sea margin'). The ship's behavior at sea and its maneuvrability at different conditions of loading can be predicted.
- To check whether the outline specification satisfies all the **legal requirements**, see page 81.
- The design information is the basis for the calculation of the building cost of the ship, that will be mentioned in the offer to the ship owner.

1.3 The tender

After having studied all the offers, the shipping company can make a final choice for a particular design and start negotiations with one or two shipyards to finalize the contract price and specification, resulting in a **contract** for the building of the ship between the ship owner and yard.

In other cases the shipping company can elaborate upon their chosen design, prepare a detailed building specification of the ship and a preliminary cost estimation. This document may be as large as 200 pages. This detailed building specification can then be sent to two or three shipyards for a more detailed offer to complete the design and construct the ship(s). This procedure is called a **tender**, and participating in it is called "to tender". For state owned companies the EU sometimes requires an "open tender" in which other shipyards, if they are from the EU, can partake.

Sometimes it can take months for the shipyards to detail the design and the specification of systems in the ship to be built and to calculate an accurate price for the tender, but they still do not receive any money and are under still no obligation.

The **financing scheme** has to be determined, often together with the bank of the shipyard, to negotiate the invoice periods with the ship owner. Some shipyards may offer financing schemes in which the shipowner only pays 10% at the signing of the contract and 90% upon at the delivery. This can be more attractive to the owner than a payment scheme that requires advance payments to the yard before building is started. Finally the order will be granted to one of the shipyards. In this process, not only price is taken into consideration, but also other factors like the delivery date, the reputation of the shipyard (working within budget and time) and whether the shipyard has constructed a vessel for the shipping company before.

1.4 The contract specification

After this preparation, sometimes lasting up to a year, the parties involved sign the final building contract. The building contract establishes all the legal positions and commercial conditions between the shipyard, the shipping company and often also the financer and is always related to a signed contract specification and a signed General Arrangement of the ship.

When the **building contract** has been signed, all the parties have obligations that start with the first down payment and end with the delivery and final payment. The shipyard gives a yard number to the future ship, which is stated on all the drawings and documentation. At this point the clock starts to tick for construction.

Within the contract there is a provision to allow for price adjustments should any changes to the original design be made during the building period. For any alterations or additional components, the additional price will be estimated, negotiated and fixed. The payment will be settled at a later date in accordance with the provisions made in the contract.

2. Design and construction

The building time, as agreed in the contract, comprises the **design phase** and the building phase. The design period varies from 6 to 18 months depending on the complexity of the ship. The building period varies between 6 and 24 months. A building team may be formed by the shipping company and the shipyard who both appoint project managers, responsible for the entire building process until delivery, each person in his or her own field of expertise.

2.1 The design and engineering department

Most shipyards have a 'Project- 'or 'Design Department' in which preliminary designs are prepared and where the final design calculations are made for the ship designs that become ship contracts. These final designs will be elaborated in every detail of the construction and systems in the ship in the **Engineering** Department. This Engineering department used to be called the **'Drawing office'**, but nowadays in most shipyards the engineering is prepared behind workstations by engineers using Computer Aided Engineering systems. There is not a single drawing table to be found. The ship is elaborated in detail in construction drawings. The diagrams of all the mechanical, hydraulic, pneumatic, and electrical systems including the accomodation, are detailed.

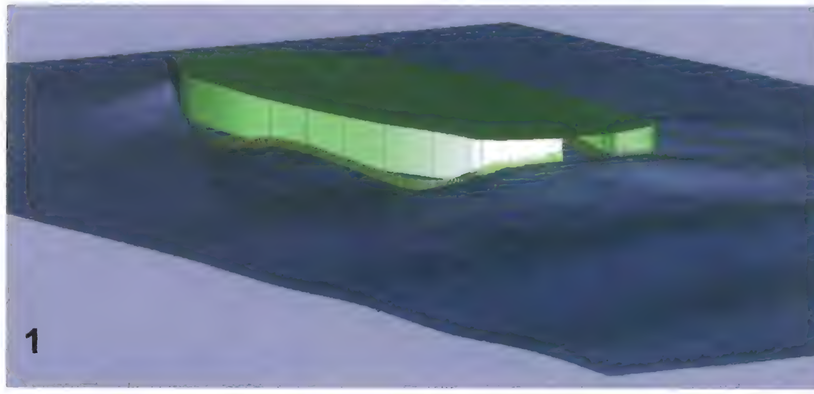
Most relevant drawings have to be submitted to the Classification Society where the ship is to be classed and to the Regulating Body (Governmental Inspectorate) in the country where the ship is to be registered (flag-state).

Even though people from the shipping company are on the building team, some drawings still need approval from the management of the shipping company. Furthermore, every detail of the engineered construction or system has to comply with the rules of the Classification Society, which regularly sends their inspectors to the shipyard to assure compliance with initially approved drawings. Some shipyards have a small engineering department, mostly focusing on project management. They will sub-contract the engineering package to an independent marine engineering office, to their co-makers for the electrical installation, engine room installation, air conditioning installation, etc., or they will co-operate with other shipyards. The detailed engineering of a ship design to a complete and approved set of drawings takes tens of thousands of even hundreds of thousands of man hours. This is costly; as a rule of thumb up to 10% of the total building price.

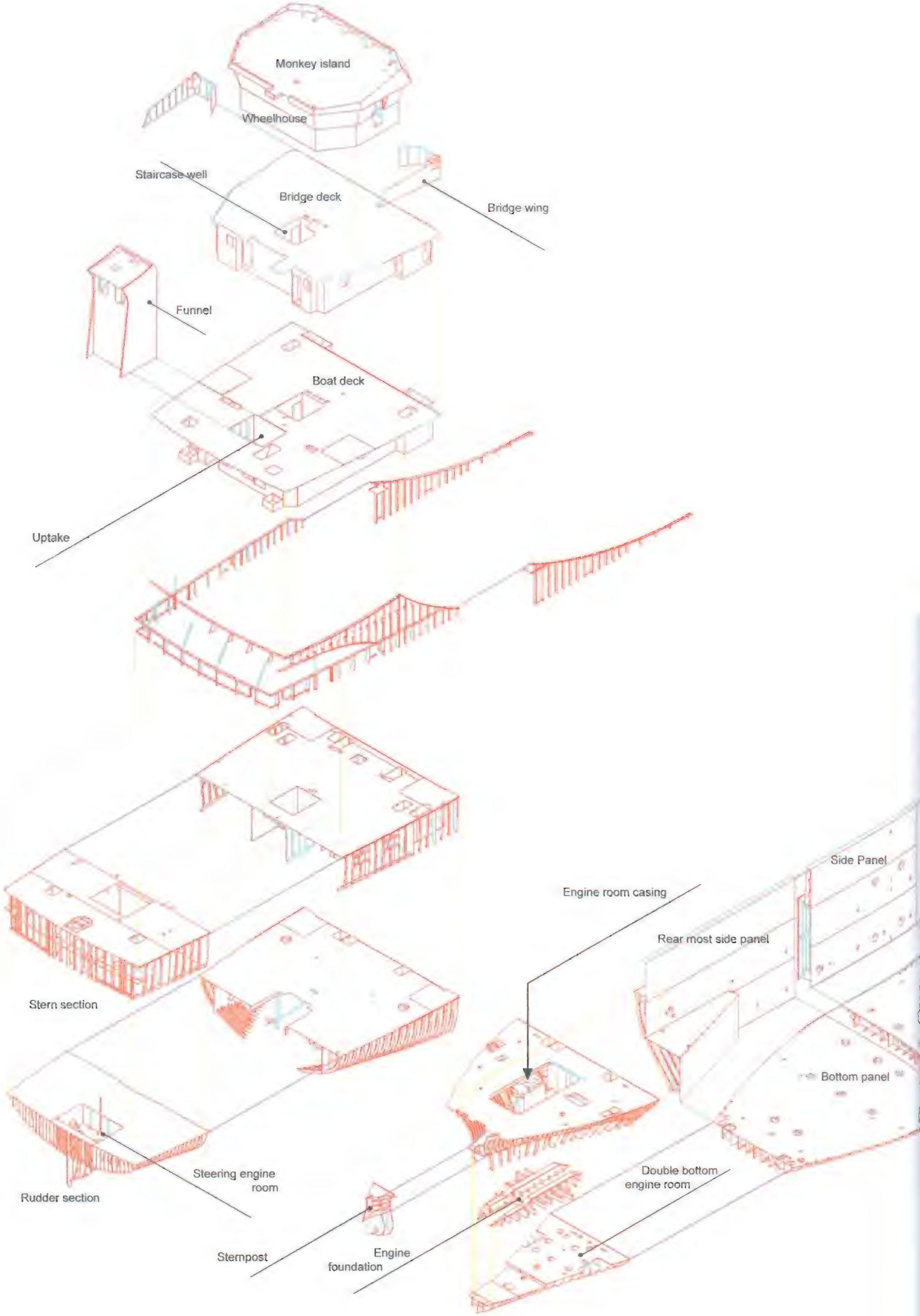
In many countries there is a good co-operation between the various shipyards, and standardization has led to a better match of products and computer-programs.
This makes it increasingly easy for shipyards to build parts for each other.

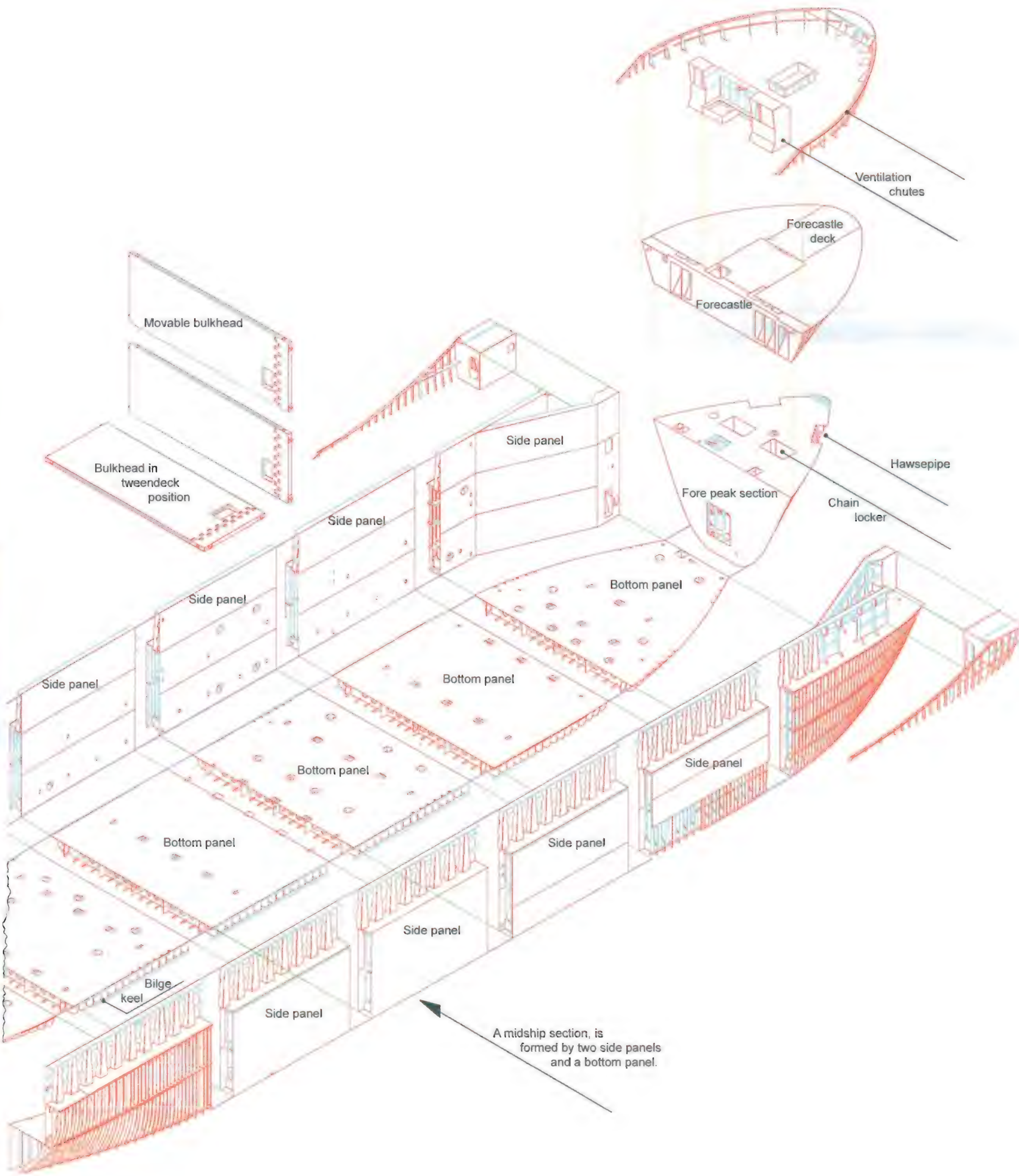
Wave-pattern before optimization

Wave-pattern after optimization



Wave-pattern around tug; computerized (1), model test (2) and under real condition (3)


Monkey island
Wheelhouse
Staircase well
Bridge deck
Bridge wing
Funnel
Boat deck
Uptake
Side Panel
Engine room casing
Rear most side panel
Stern section
Bottom panel
Steering engine room
Rudder section
Double bottom engine room
Sternpost
Engine foundation



Panels (blocks) and sections of a ship

Cruise liner during seakeeping and manoeuvring tests at MARIN

2.2 Specialist knowledge

For certain difficult areas of design, specialized research and engineering firms are consulted. These firms can advise shipyards in:

- the optimization of the shape of the ship
- calculations on noise and vibrations
- the optimization of the propellers, ducts and rudders.

Research on the hull is done both by computer calculations and results of model testing in a model tank. The **resistance curves** are obtained by measuring the required propulsion power at different drafts and speeds. In addition to this, research is done on the influence of waves on speed, the necessary **propulsion power**, navigability, rolling and pitching behavior and maneuvrability. With very large ships research is done on the extreme forces and moments of inertia that arise in the ship in case of heavy waves/seas.
The optimization of the ship's shape is a very laborious task where measuring and calculating go hand in hand.

In the figures (previous page) the wave patterns of a ship at a certain speed before and after optimization are shown. After optimization the ship makes fewer waves, so the optimization procedure has reduced the wave resistance. The **bulbous bow** has already reduced this resistance because the wave produced by the bulbous bow counteracts the bow wave. However, this is only one effect that is accounted for in the optimization process, there are many other effects that can further minimize wave resistance.

2.3 Production preparation and pre-fabrication of steel parts

The production preparation department gets the construction drawings from the engineering department to prepare the material ordering lists and the job-descriptions for the production of the block sections. Every individual steel part gets its own individual code, (the 'pos-number'), and description, type of material, block section number, etc.
With the aid of a computer-program, a nesting engineer 'nests' a collection of steel parts with the same material type and thickness in rectangular steel plates The goal of the nesting process is that the construction parts for the ship are located in such a pattern in the available steel plates that there is a minimal amount of waste material after cutting all the parts out of the base-plate.

On the Numerical Controlled (NC) steel cutting machine, a computer also controls the cutting torch, for instance an autogenous flame cutting torch or a plasma cutter in a water bath (wet-plasma). In the 'wet-plasma' cutting process, the excess heat is drained quickly and the cutting fumes are absorbed into the water. Some shipyards use 'dry plasma' cutting where a vacuum system below the plate draws the fumes away.

As a result minimal distortions will occur in the pre-fabricated steel construction parts and there is good control of the exact dimensions of the plates. The cutting machine can also mark a part's code number on the steel.

2.4 The production phases

A ship is constructed in various stages, which can sometimes overlap:

- pre- fabrication of steel parts
- building of flat panels (plates with stiffeners)
- building of block-sections (3 dimensional parts that can still be moved from a workshop to the slipway)
- assembling of hull and deckhouse on a slipway or in a building dock
- installation and outfitting of systems and components
- painting of individual parts
- final paint layers on the outside hull
- launching of the ship
- outfitting alongside a quay and subsequent completion
- system trials at the shipyard
- sea trial.

View of an assembly shop

A plate cutter

Automation of the construction has led to more efficiency. Furthermore, the sections are engineered in such a way that as much assembly welding as possible can be done by semi-automatic welding and robots. Building by **block-section** enables parts of the double bottom, the fore ship and the aft ship to be welded whilst lying upside down in the workplace.
This manner of welding produces a uniform quality of the welds within less time. Because access to the different blocks is much more restricted when they are joined together, the ships systems are pre-outfitted in the sections as far as possible, prior to the joining. This means that piping systems, tanks, filters and other small auxiliaries are all placed in the section before the joining of all the blocks.
The building of a ship used to begin with the placing of a keel plate. The rest of the construction was then connected to this first item. Today, laying the keel means that the first bottom block is placed in the assembly hall or on the building berth. Subsequently, the other blocks of the ship are then built to or on this. At this stage, the production is well underway.
Some modern shipyards do the actual building in large indoor assembly halls where they use pre-painted steel plates. After welding the plates, the joints are immediately painted.

Several factors determine where the ship will be finished. The finishing is either done in the assembly hall or at the outfitting dock. In some cases the deckhouse can not physically fit into the assembly hall. If the vessel is going to be launched longitudinally, the vessel should have the minimal amount of weight on board. The **launching** of a ship can be longitudinal or transverse (side launching), depending on the lay-out of the shipyard and the slipway and is always an exciting moment because at the moment the ship is launched, there is no going back.

A side-launch

The main engine (700 tons) is brought on board

The first bottom block is placed.

Installation of a complete deckhouse, while the ship is at the fitting out dock.

2.5 Launching and outfitting

In longitudinal launches from a slipway, the ship acquires so much speed that it takes a lot of effort to reduce this speed. This is done by water brakes and drag chains or ropes. In side-launches, from a transversal slipway, the ship can bounce back against the wharf, especially when the water level is high. The ship does not gain much speed, but instead produces very high waves.

After the launch, the final items such as masts, hatches, engines, funnel, ventilation shafts, cranes etc. are added to the ship at the fitting-out berth. Finally, the cabins and other spaces are furnished and the inventory is brought on board. (Inventory is not a yard supply, apart from some basics, they are normally supplied by owners).

2.6 Commissioning

When the ship's electrical systems are ready, the switchboard is connected to the shore supply to get power. After careful checking, a diesel generator is started, and electric power from the generator is supplied to the switchboard and the ship can then begin to function independently from the shore power. Upon completion of the vessel in the shipyard the final testing of all systems will be conducted at the shipyard with the exception of items which can only be tested during sea trials in open sea.
Final testing at the shipyard is related to electrical systems, engines,generators, pumps, technical equipment, life-saving equipment light ship weight measurement, and the **inclining experiment** (the stability test).
In principle all these tests will be carried out in the presence of the owner's representative(s), Classification surveyor(s) and, if applicable, National Authority representative(s). (Final testing in open sea is mainly related to final testing of machinery under working conditions, fuel consumption, vessel's speed, rudder tests and anchor tests.)

Next is the first, technical, **sea trial**, which can take from a few hours to several days. This is the first time that the ship leaves the shore and is completely self-reliant. The ship as a whole and all of its parts are extensively tested and all the results are carefully recorded. The Classification Society and the National Shipping Inspectorate (flag state) are also present to see if all requirements are met.

In general, these trials are successful, but there are always small imperfections which can be corrected during or after the trial. The exact behavior of the ship in open sea will become clear when the ship is in use; however, the speed and fuel consumption of the empty ship can be measured during sea trials.

> During commissioning a very important item is the inclination test and the lightweight measurement. The inclination test is carried out to find the height of the center of gravity. Moving a known weight from midships to both sides alternatively and measuring list very accurately during the various steps in that procedure make it possible to calculate the position of 'G'. This is a very important figure for stability calculations.

2.7 Production logistics

More and more shipyards advertise shorter delivery periods, and more and more shipping companies stipulate it. In order to facilitate this trend, many of shipyards sub-contract other shipyards to build parts of the ship. It is also common that the hull of the ship is constructed in low-wage countries and that the hull is fitted out and completed locally. But even without these measures, all the semi-finished parts must be ready for the next phase of construction to commence. Additionally, all the purchased parts must be ready in time, but not too early because of the costs for storage and interest.
Keeping the construction process manageable requires that a proper overall planning of the project in terms of technicalities, logistics and

Sea trial test of a multi purpose ship

finance should be available any time of the day.
Such a management system integrates and controls data from the preparation, design, purchase, stocks, production, administration and project management.

3. Delivery

3.1 Sea trials

The Shipping Company and Certifying Authorities will finally accept the ship subject to the issue of the relevant certificates and successful sea trial tests. During a short voyage the protocol of consignment is signed, the shipyard's flag will be exchanged for the flag of the shipping company and the financer pays the last installment. Because there is usually a 12-month period of **guarantee** on the ship, the shipping company usually requires a bank guarantee from the shipyard. This is called upon when the shipyard cannot, or refuses to comply with the guarantee. It is normal that in the first month of a ship's life a guarantee engineer from the shipyard is on board.

3.2 Period of Guarantee

The guarantee conditions are an integral part of the building contract. In general, the guarantee period is 12 months after the delivery of the vessel. The shipyard almost always takes over the guarantee conditions and periods of the companies supplying the different ship components and transfers them to the shipowner at delivery. If the ship needs repairing within the period of guarantee, the vessel's location and the urgency of the repair jobs determines who will repair the vessel and where it will be done.

If the ship cannot be repaired at or by the shipyard, for instance, because the ship is in another country, the shipping company is allowed to have the ship repaired by a third party, but only if the costs of repairing the ship are not more than the price the shipyard would ask.
This condition protects the shipyards against excessive bills if there is a deal between the shipping company and the repair yard.

Repairs of components and equipment are almost exclusively done by local service-dealers, especially when the parts are of a well-known brand. This is always done in consultation with the shipyard or the supplier. The crew is prohibited from conducting repairs during the period of guarantee unless the repairs are absolutely necessary. In this case, the shipyard has to be contacted for consultation first.

Sometimes suppliers have two periods of guarantee for their product. The first period covers a period of months after delivery from the factory; the second, after the product is put into operation. The reason for this is, that there sometimes is a long period between delivery to the shipyard and the time the component is put into operation.

CHAPTER 5

Forces on a ship

1 General

When a ship is moving through the water, there are many forces acting on it. How they act is largely determined by the purpose the ship was built for. Forces on a tugboat will be different from the forces acting on a container ship. The types of forces that occur in waves are the same for every ship but the magnitudes and points of action depends on the shape of the ship below and immediately above the waterline.

The pattern of forces on a ship is very complicated and largely depends on the following parameters:

- the weight of the empty ship (light ship weight)
- the weight and distribution of the cargo, fuel, ballast, provisions, etc.
- hydrostatic* pressure on the hull applied by the water
- hydrodynamic* forces resulting from the movement of the ship in the waves
- vibrations caused by engines, propeller, pitching
- incidental forces caused by docking, collisions
- ice

A ship with heel in an unstable situation.

These and other forces cause the ship to deflect. When the force disappears, the ship will regain its original shape. Every ship is different and have more or less flexibility. If, however, the forces exceed a certain limit, permanent deformation can result.

2 Longitudinal Strength

2.1 Shearing Forces

When a ship is in calm water, the total upward force will equal the total weight of the ship. Locally this equilibrium will not be realized because the ship is not a rectangular homogeneous object. The local differences between upward pressure and the local weight give rise to shearing

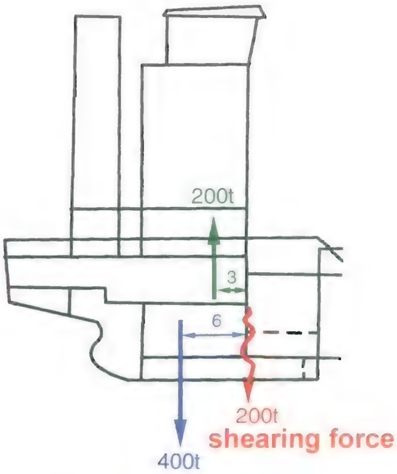
*Static and dynamic
The concepts static and dynamic are widely used in this and other chapters. Static means that the force exerted on an object is absorbed immediately. Dynamic means the force is absorbed gradually.

Examples of static:
- A swing with a child is slowly pushed forwards. This is a static movement because the force exerted on the swing is absorbed instantaneously.
- A crane on a ship is loading cargo. As the cargo runner is stiffened, the ship lists slowly. This is a static movement because the ship absorbs the force that lifts the weight instantaneously.

Examples of dynamic
- The same swing is pushed forward suddenly. The weight of the swing cannot absorb this sudden burst of force and loses control. This is a dynamic motion.
- The same crane has lifted the weight several meters. The cable suddenly snaps and the weight falls on the quay. This causes the ship to list violently to the other side. The ship is unable to absorb the sudden change in weight and, as a result, acquires a dynamic motion.

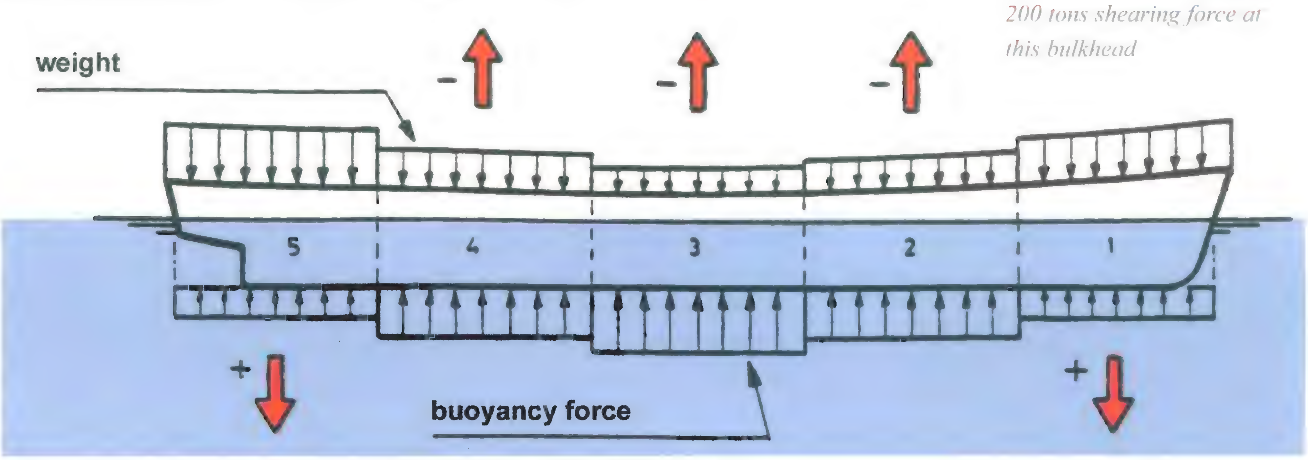
forces that lead to longitudinal tensions. The **shearing force** is the force that shifts the (transverse) plane from one part of the ship to another.
The submerged part of the ship clearly shows the difference in volume between midship, fore and aft ; this is the reason for the difference in upward force.
In the drawing on the right of this page a part of the aft ship is shown along with the shearing force near a bulkhead. The shearing force at the bulkhead is 400 – 200 = 200 tons. The downward force causes a **hogging moment** of 400 tons x 6 meters. The upward force causes a sagging moment of 200 t x 3m.
The **bending moment** at the bulkhead is: 2400 tm – 600tm = 1800tm (hogging).

The longitudinal forces occur because:
a. the weights in the ship are not homogeneous fore and aft
b. the upward force differs due to the shape of the underwater body.

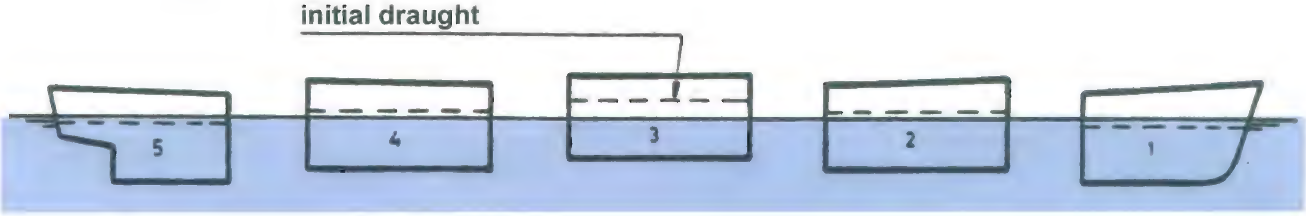


200 tons shearing force at this bulkhead

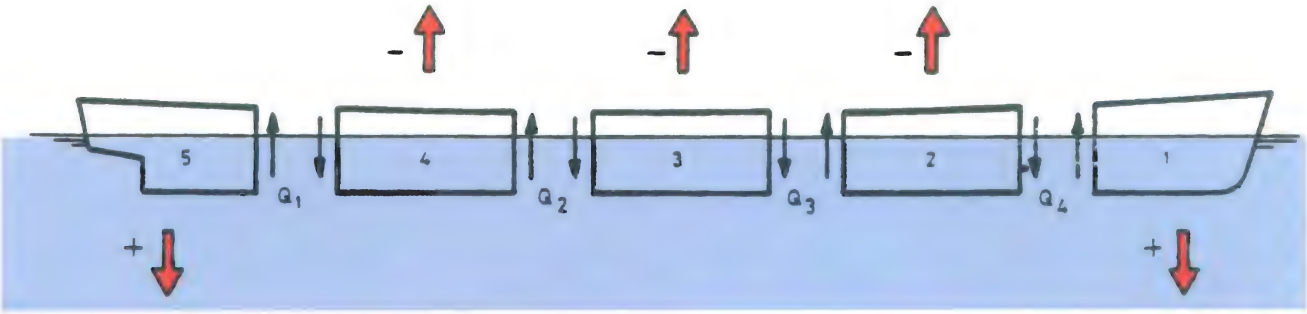

The submerged part of this ship clearly shows the difference in volume between the midships section and the aft ship. This explains the difference in upward pressure.



The black vectors represent the upward pressure and the weight of the ship.
The red vectors indicate the resultant per section.



This is how the separate compartments would float. The dashed line indicates their actual draft.



The black vectors indicate the resultant shearing forces between the different compartments.
The red vectors indicate the resultant per section.

2.2 Explanation of bending moments

Below is an explanation of how bending moments and shearing forces are continuously changing. As an example a rectangular vessel is used which is divided into three compartments (A, B and C). In figures 1, 2 and 3 both outer compartments are filled with cargo. In fig. 4 and 5 the inner compartment (B) is filled with cargo. In fig. 2 and 5 the vessel is on a wave crest and in fig. 3 and 6 the vessel is in a trough. The upward pressures keep changing because the wave is moving along the barge. The downward forces, however, stay the same. The up and downward forces per compartment are shown as vectors.

The mean resultant per compartment is given as a vector on the line below.

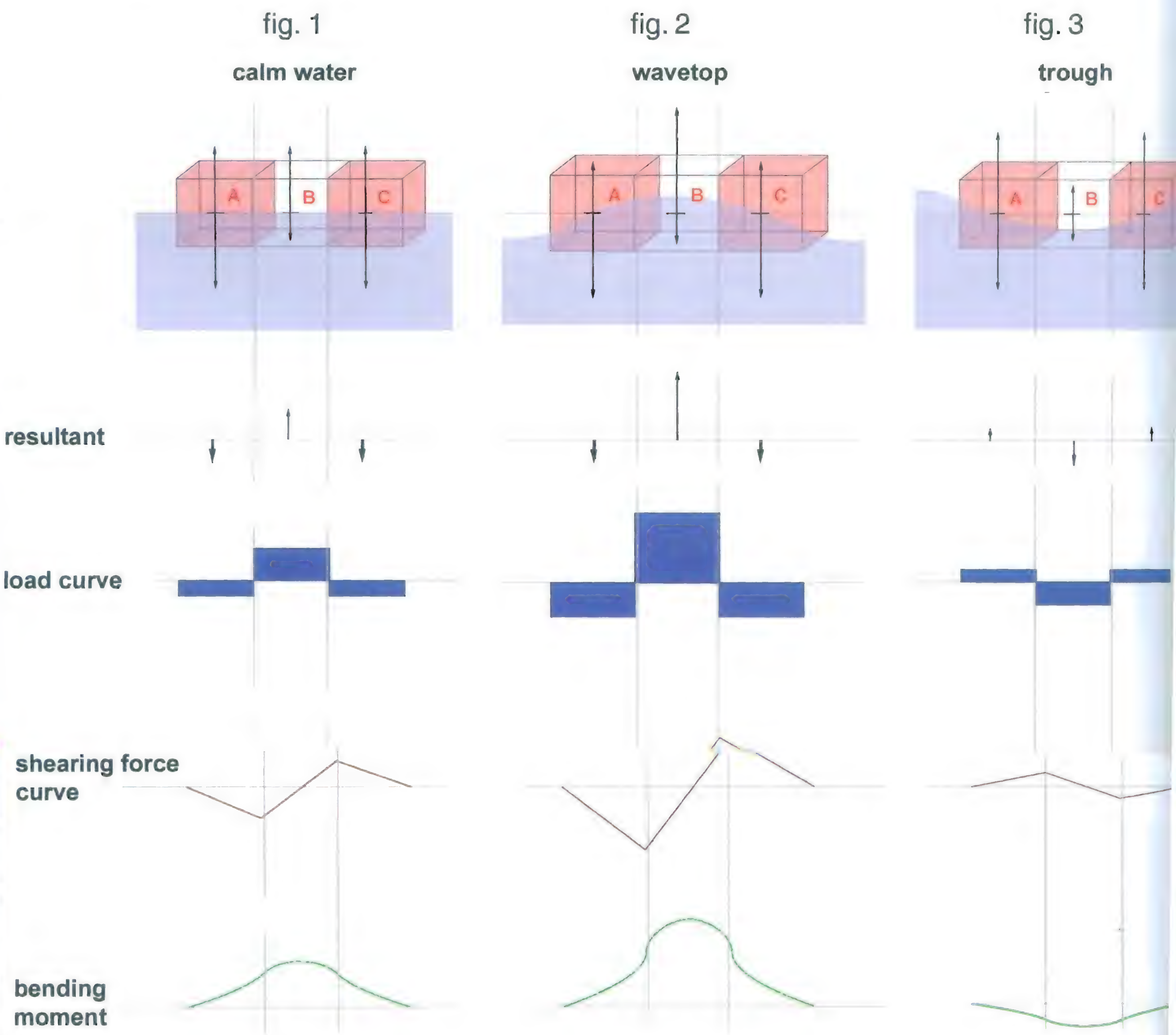
The load curve indicates the difference of the up and downward forces per meter at each point on the baseline. The sum of the areas above the baseline and the areas below the baseline should be equal.

The shearing force curve indicates a sum of the shearing forces on the right part produced by the left side, going from left to right. If the direction of the force changes (from upward to downward or vice versa), the shearing force curve will either descent or ascend. The shearing force curve has an extreme value at the points where the direction of the force changes.

Converting the load curve to a shear force curve is called summing. The sum of the areas above the baseline has to equal the sum of the areas below the baseline.

The shearing forces are expressed in tons. The bending moment is determined by summing the shearing forces from left to right.

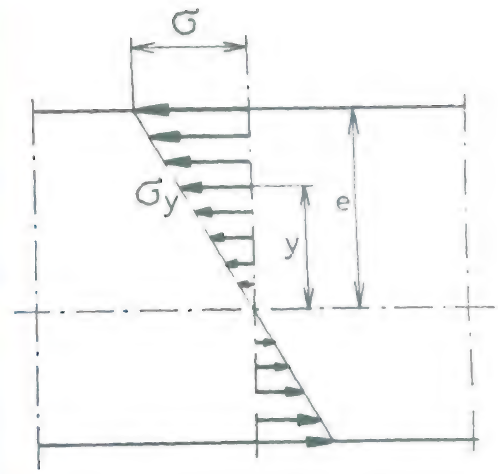
The bending moment is expressed in ton-meter (tm). If the shearing force curve descents or vice versa, the bending moment will bend from "hollow" to "round" or vice versa. When the shearing force curve crosses the baseline, the bending moment line will descent or ascent.



The ship will take the shape of the bending moment line if this has only one extreme (maximum) value.
The situation in figures 1 and 2 is called a hogging condition and the situation in figures 3, 4, 5 and 6 is called a sagging condition.
Around mid-height of the rectangular cross-section of the barge vessel there is a "neutral zone". At that level there are no tension or compression stresses. Further above or below the stresses have a higher value, as can be seen from Hook's Law stress distribution.
On the diagram of the bending moment, the maximal bending moment is at half length, (½ L), decreasing to zero (0) at the ends.
In a ship we find a similar stress distribution.

Hogging:
The vertical deflection of a ship's hull, in longitudinal direction, where the hull is bent upwards midships, as a result of cargo distribution and/or the way the ship is supported by a wave. (see page 98)

Sagging:
The vertical deflection of a ship's hull in longitudinal direction, where the hull is bent downward midships, as a result of cargo distribution and/or the way the ship is supported at sea.

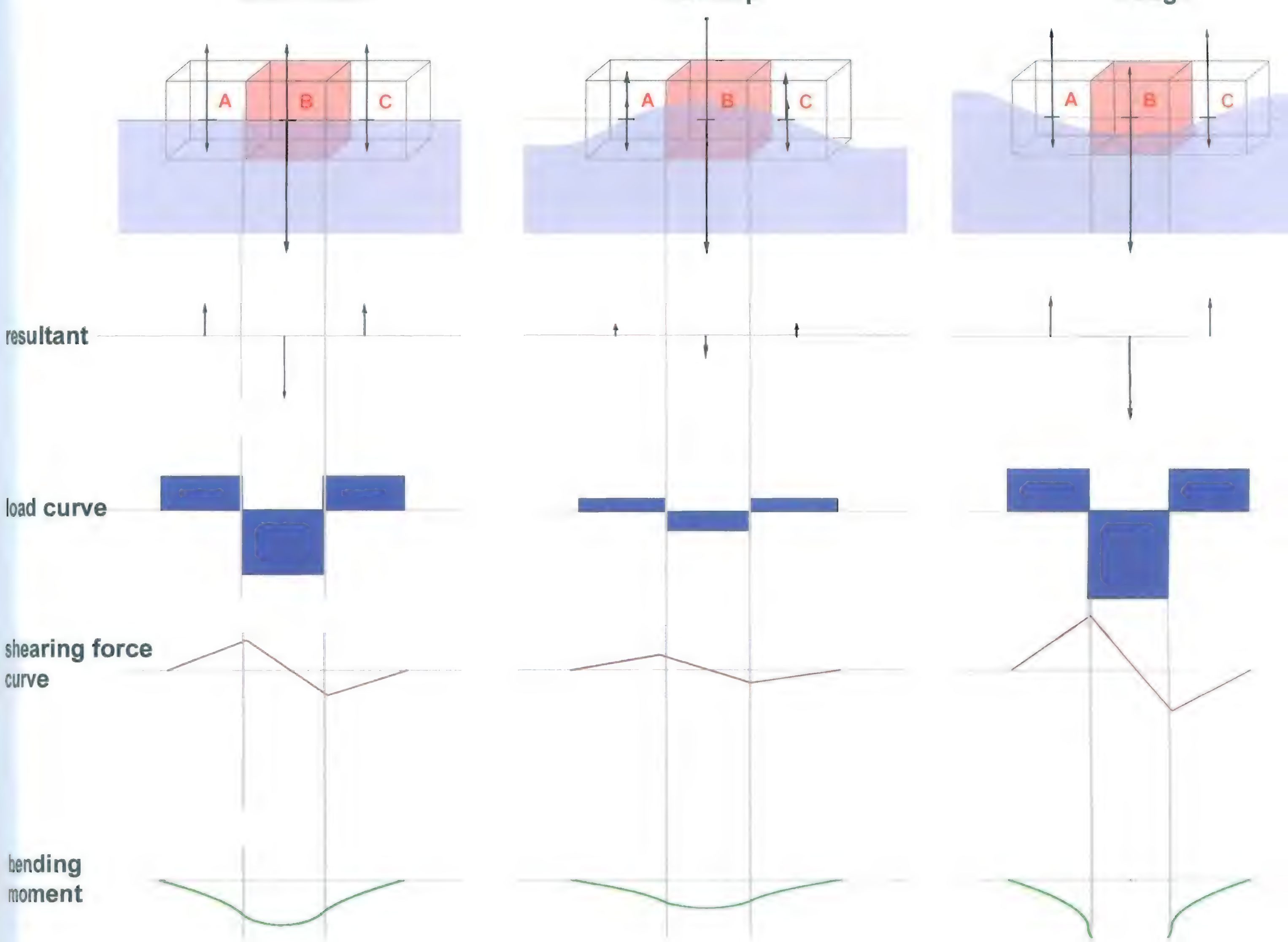


Stress distribution in a beam, during bending. The neutral axis is at the level of the center of gravity of the sections.

fig. 4 **calm water**

fig. 5 **wavetop**

fig. 6 **trough**



1. Upper strake side bulkhead (22 mm)
2. Main deck (14 mm)
3. Longitudinal or side bulkhead (9 mm)
4. Deck longitudinal, Holland-Profile (HP profile)
5. Deck longitudinal (flat bar)
6. Longitudinal (HP-profile)
7. Web frame with plate stiffeners around manhole
8. Inner side of the shell with stringer
9. Longitudinals on the side bulkhead.

Container feeder in heavy weather. The ship is partially on a wave top; hogging

The ship is partially in a trough. In this case the fore-ship will experience a large sagging moment while the aft ship experiences a large hogging moment.

2.3 Longitudinal Reinforcements

At mid-length the longitudinal stresses in the extreme top (deck) and bottom area are maximal (see page 98-99).
To keep the stresses in these areas below the maximum allowed, much material is needed in those areas. This can be achieved by installing thicker deck plates, sheer strake, bottom plating and bilge strake, including the longitudinal stiffening attached to that plating.
In the double bottom, the tank top with its stiffening also has to be taken into consideration.
Using material that can withstand higher stresses (high tensile steel) can reduce the weight of the material in those areas.

The pictures above clearly show the difference in plate thickness between the upper strake of the side bulkhead and the side bulkhead just below it. In this ship (container feeder) the upper strake of the side bulkhead is about 2.5 times as thick as the continuous side bulkhead. The place where the plate thickness changes (from 22 mm to 9 mm) is called the taper.

2.4 The loading Program

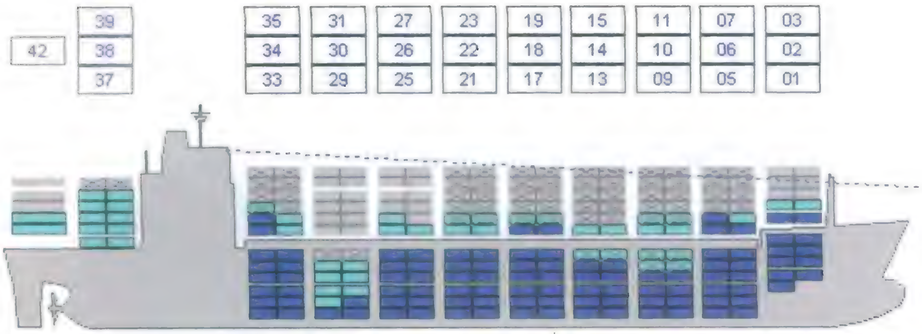
To judge if stresses are within limits, there is a Classification Rule that each ship over 65 meters in length has on board a loading instrument, a computer with a program that calculates the stresses in the ship, in accordance with the cargo on board.

When a ship's officer has entered the weight of all the items into the **loading instrument,** (this is normally done before they are actually loaded on board), the computer can calculate shearing forces, bending moments and stability.

The program compares the situation as proposed with the requirements and regulations of the Classification Bureau and the flag state. Two calculations are made: **harbor condition** and **sea condition**. In port, higher stresses are allowed, as the influence of waves is absent. This gives the possibility to allows loading and unloading sequences to adapt to these higher stresses. Upon completion of cargo handling, the ship has to fulfill sea conditions.

Pages 102 and 103 contain an example of a stress calculation with the related curves.
Of the total loading programme, only a few examples are shown on the next pages.

Total failure due to incorrect sequence in cargo and / or ballast handling.



11	10	Total	9	8	7	6	5	4	3	2	1	Hatch no.
0	0	458	65	18	109	32	52	46	33	51	52	No of 20's
14	20	333	46	20	10	59	54	32	37	29	12	No of 40's
14	20	791	111	38	119	91	106	78	70	80	64	Total No
0	0	8184	1196	402	2007	644	987	881	225	908	932	Wgt of 20's
203	78	7975	1297	87	271	1683	1452	823	951	783	346	Wgt of 40's
203	78	16158	2493	490	2279	2327	2439	1704	1176	1690	1279	Total Wgt
4	0	284	46	4	58	35	64	33	5	33	2	Live reefers

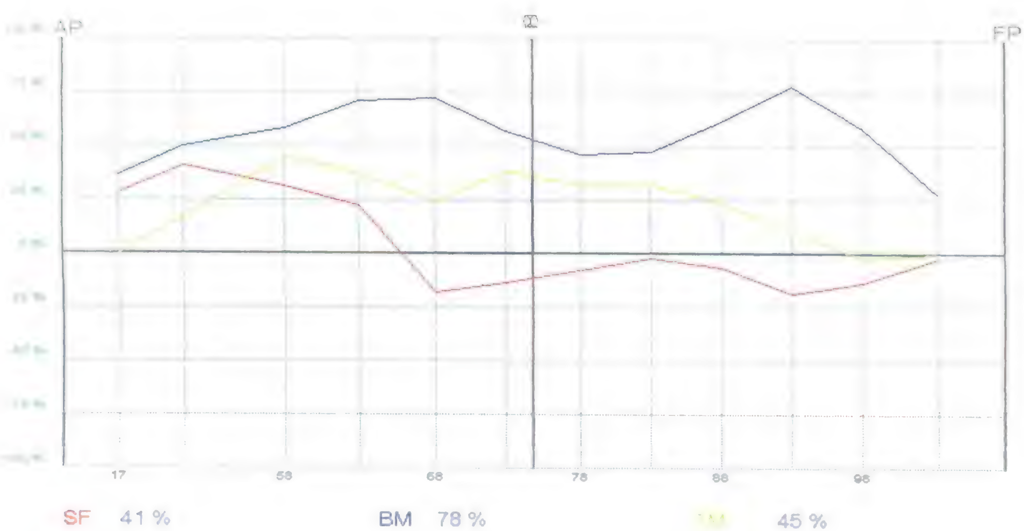
Weights	
Displacement	32794
Dead weight	20450
Cargo weight	16158
Ballast weight	1909
Fuel weight	1809
Misc. weight	574

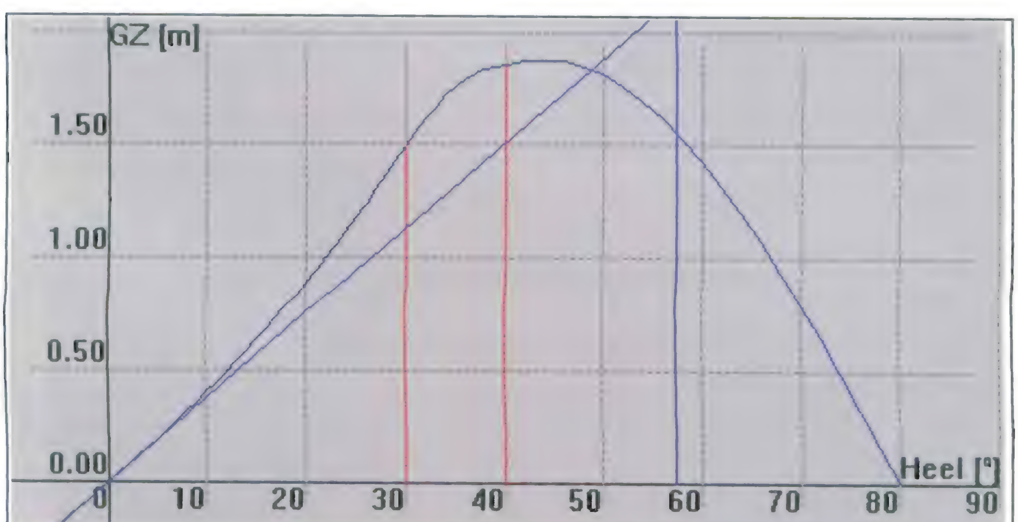
Trim and Drafts	
Draft FP	8.82
Draft AP	9.11
Draft mean	8.97
Trim	0.29
Heel Port	0.04

GM	
G'M	2.17
GM Req	0.60

Limits: Sea Condition	
SF	41.2
BM	78.3
TM	45.3
Seawater Dens	1.023

Vessel Center of Gravity	
LCG	91.90
TCG	0.00
VCG	11.79





Intact Stability | Weather | GZ Table

A.749(18)	Area 0-30 (m-rad)	Area 30-40 (m-rad)	Area 0-40 (m-rad)	GZ(30+) (metres)	U Max (deg)
Required	0.055	0.030	0.090	0.200	25.000
Actual	0.351	0.302	0.653	1.878	43.771

Abbreviations

GZ, GM see chapter 16

SF = Shear Force
BM = Bending Moment
TM = Torsion Moment
LCG = Longitudinal Center of Gravity
TCG = Transverse Center of Gravity
VCG = Vertical Center of Gravity
FSM = Free Surface Moment
FP = Fore Perpendicular
AP = Aft Perpendicular
tm = ton-meter
rad = radial
Dens = Density
Wgt of 20's = Weight of 20 feet containers.

Tank Groups												
Water Ballast	8360.90	1862.46		1909.02		41.00		88.72	2.50	-0.22	0.00	0.00
FPT	557.80	0.00	0.00	0.00	0.0	0.00	1.025	177.35	0.16	0.00	0.00	0.00
1C	534.50	0.00	0.00	0.00	0.0	0.00	1.025	163.63	0.06	0.00	0.00	0.00
2FP	658.40	0.00	0.20	0.00	0.0	0.00	1.025	151.92	0.11	0.93	0.00	0.00
2FS	658.40	0.00	0.00	0.00	0.0	0.00	1.025	151.92	0.11	-0.93	0.00	0.00
2AP	374.10	0.00	0.00	0.00	0.0	0.00	1.025	137.77	0.11	1.89	0.00	0.00
2AS	376.00	0.00	0.00	0.00	0.0	0.00	1.025	137.77	0.11	-1.89	0.00	0.00
3DP	519.90	0.00	0.00	0.00	0.0	0.00	1.025	114.97	0.01	3.76	0.00	0.00
3DS	523.10	0.00	0.00	0.00	0.0	0.00	1.025	114.97	0.01	-3.76	0.00	0.00
4DP	680.80	680.80	1.80	697.82	100.0	0.00	1.025	88.74	0.92	6.81	0.00	0.00
4DS	684.10	684.10	1.80	701.20	100.0	0.00	1.025	88.72	0.93	-6.78	0.00	0.00
4HP	508.40	234.15	4.01	240.00	46.1	20.50	1.025	88.68	6.70	14.07	0.00	0.00
4HS	508.40	263.41	4.51	270.00	51.8	20.50	Use Max FSM	88.68	6.95	-14.07	0.00	0.00
5DP	500.20	0.00	0.00	0.00	0.0	0.00		63.13	0.01	3.47	0.00	0.00
5DS	501.50	0.00	0.00	0.00	0.0	0.00	1.025	63.13	0.01	-3.47	0.00	0.00
APT	775.30	0.00	0.00	0.00	0.0	0.00	1.025	10.85	8.25	0.00	0.00	0.00
Fuel Oil	4626.90	1734.73		1715.33		344.62		100.94	6.40	0.44	0.00	0.00
3FP	556.60	0.00	0.00	0.00	0.0	0.00	0.980	132.82	1.90	7.88	0.00	0.00
3FS	556.60	0.00	0.00	0.00	0.0	0.00	0.980	132.82	1.90	-7.88	0.00	0.00
3AP	649.50	607.00	10.66	600.93	93.5	15.84	0.990	114.66	6.40	12.85	0.00	0.00
3AS	649.50	602.00	10.55	595.98	92.7	15.84	0.990	114.67	6.35	-12.84	0.00	0.00
4P	157.40	136.00	2.53	134.64	86.4	19.80	0.990	88.37	3.12	14.00	0.00	0.00
4S	157.40	122.00	2.29	120.78	77.5	19.80	0.990	88.35	3.00	-13.99	0.00	0.00
5FP	258.80	26.26	0.51	26.00	10.1	66.93	0.990	67.54	2.06	12.31	0.00	0.00
5FS	428.30	36.36	0.69	36.00	8.5	73.34	0.990	67.52	2.15	-12.35	0.00	0.00
5AP	459.50	0.00	0.00	0.00	0.0	0.00	0.990	53.58	1.80	9.01	0.00	0.00
5AS	459.50	0.00	0.00	0.00	0.0	0.00	0.990	53.58	1.80	-9.01	0.00	0.00
1HFO	65.00	61.22	6.52	60.00	94.2	22.54	0.980	45.58	12.40	1.94	0.00	0.00
2HFO	64.90	61.22	6.53	60.00	94.3	22.54	0.980	45.58	12.41	-3.48	0.00	0.00
HFOSETT	100.70	81.63	5.63	80.00	81.1	85.26	0.980	45.55	11.95	8.85	0.00	0.00
OFLOW	63.20	1.02	0.12	1.00	1.6	2.73	0.980	43.47	0.07	-3.21	0.00	0.00
Diesel Oil	208.00	104.71		89.00		51.00		60.20	10.70	6.24	0.00	0.00
DOTP	169.50	70.59	2.42	60.00	41.6	8.50	0.850	67.10	6.81	14.07	0.00	0.00
DOSERV	38.50	34.12	2.29	29.00	88.6	42.50	0.850	45.93	14.63	-9.96	0.00	0.00
Fresh Water	397.10	161.00		161.00		256.00		5.84	14.94	0.25	0.00	0.00
FWTP	181.90	82.00	1.48	82.00	45.1	118.00	1.000	6.34	15.01	12.56	0.00	0.00
FWTS	215.20	79.00	1.22	79.00	36.7	138.00	1.000	5.33	14.87	-12.54	0.00	0.00
Lubricating Oil	364.50	137.74		123.97		135.00		24.59	9.82	-6.87	0.00	0.00

Still Water Shear Force, Bending Moment and Torsion Limits

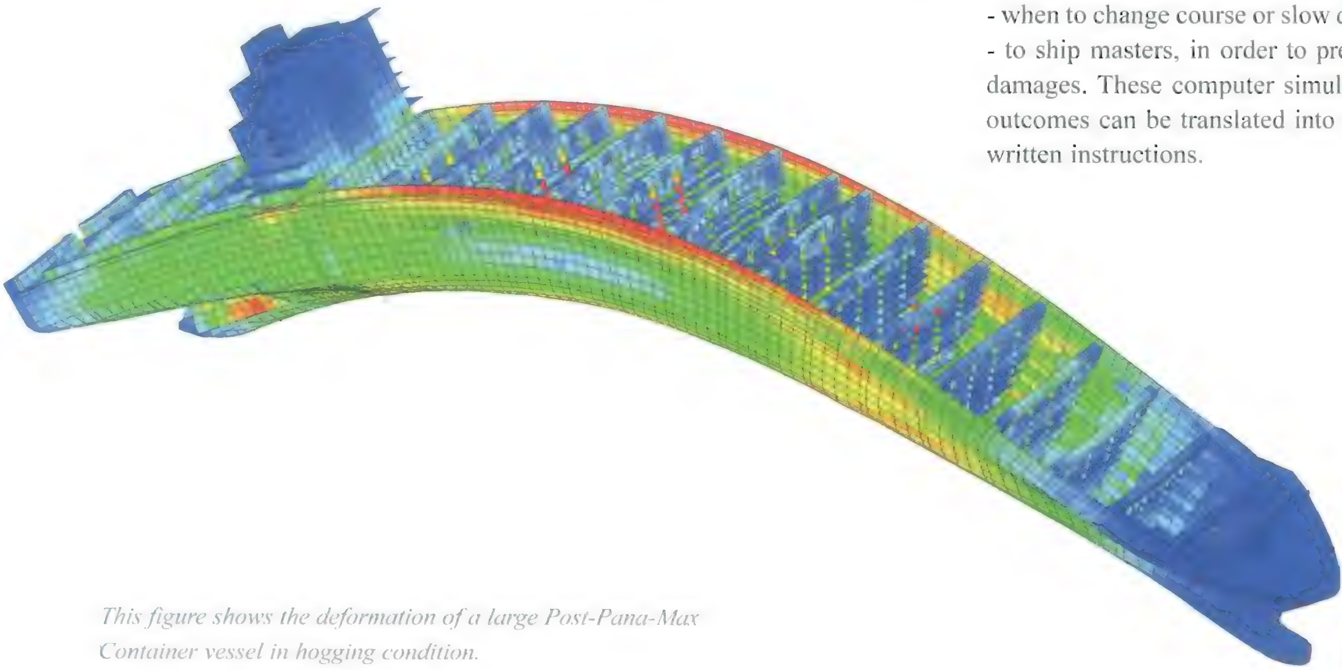
		BENDING MOMENT				SHEAR FORCE				TORSION MOMENT		
Frame No.	Distance to AP m	Actual Value tm	Min Allow tm	Max Allow tm	Relative %	Actual Value t	Min Allow t	Max Allow t	Relative %	Actual Value tm	Max Allow tm	Relative %
103	174.10	2202	-5650	8150	27	-83	-3950	3750	2	-4	2899	0
98	159.90	9989	-9900	17100	58	-768	-5450	5150	14	-81	2899	3
93	145.70	25845	-21000	33000	78	-1175	-5900	6100	20	293	2899	10
88	131.50	38870	-45900	62700	62	-409	-5250	5550	8	699	2899	24
83	117.30	43575	-72300	92400	47	-128	-5600	5550	2	941	2899	32
78	103.10	50723	-86700	108000	47	-465	-5550	5550	8	932	2899	32
73	88.70	62499	-86700	108000	58	-811	-5650	5650	14	1128	2899	39
68	74.30	78416	-86900	108000	73	-1077	-5700	5800	19	696	2899	24
63	59.90	77600	-90600	108000	72	1303	-5500	5800	22	1079	2899	37
58	44.70	58470	-86900	100000	58	1201	-3700	3850	31	1313	2899	45
33	24.70	28169	-48000	55250	51	1587	-3750	3850	41	498	2899	17
17	11.90	9708	-23100	26600	36	1182	-4050	4100	29	-18	2899	1

Max. SF :		41.2 % at	24.70 m	Displacement :	32794 t	Draft FP :	8.82 m	Heel P :	0.04 °
Max. Shear Force :	1587 t	41.2 % at	24.70 m	Deadweight :	20450 t	Draft AP :	9.11 m	Trim :	0.29 m
Max. BM :		78.3 % at	145.70 m	Seawater Dens.	1.023 t/m3	Draft Mean :	8.97 m		
Max. Bending :	80699 tm	74.7 % at	67.74 m						
Max. TM :	1313 tm	45.3 % at	44.70 m						

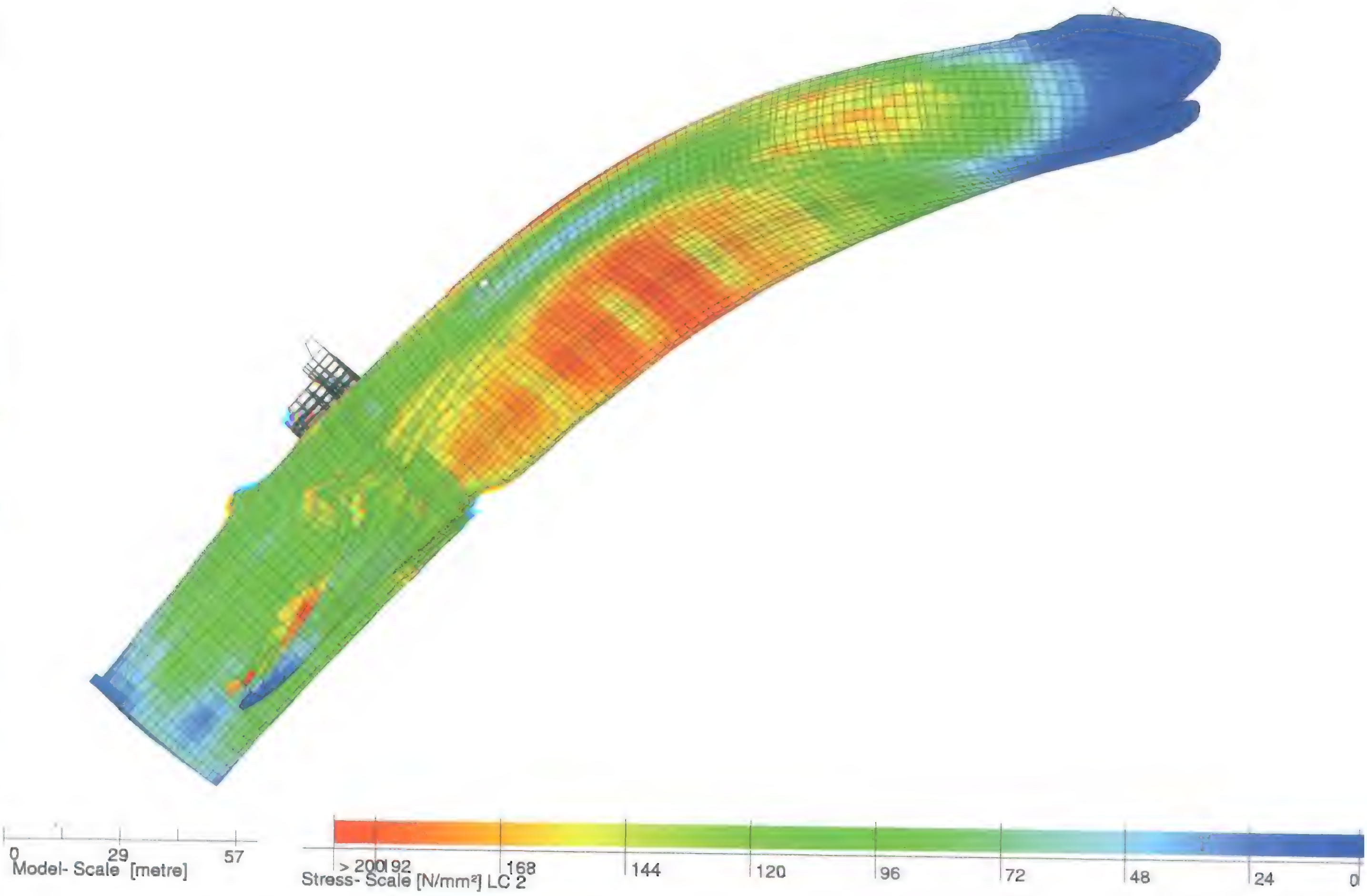
2.5 Stress distribution and deflection simulation

Stresses in and deflections of the ship's hull, due to the various forces working on ships encountering heavy waves, can be simulated in computer models. The following pages show the stress distribution exaggerated in colors, the consequential deflection.

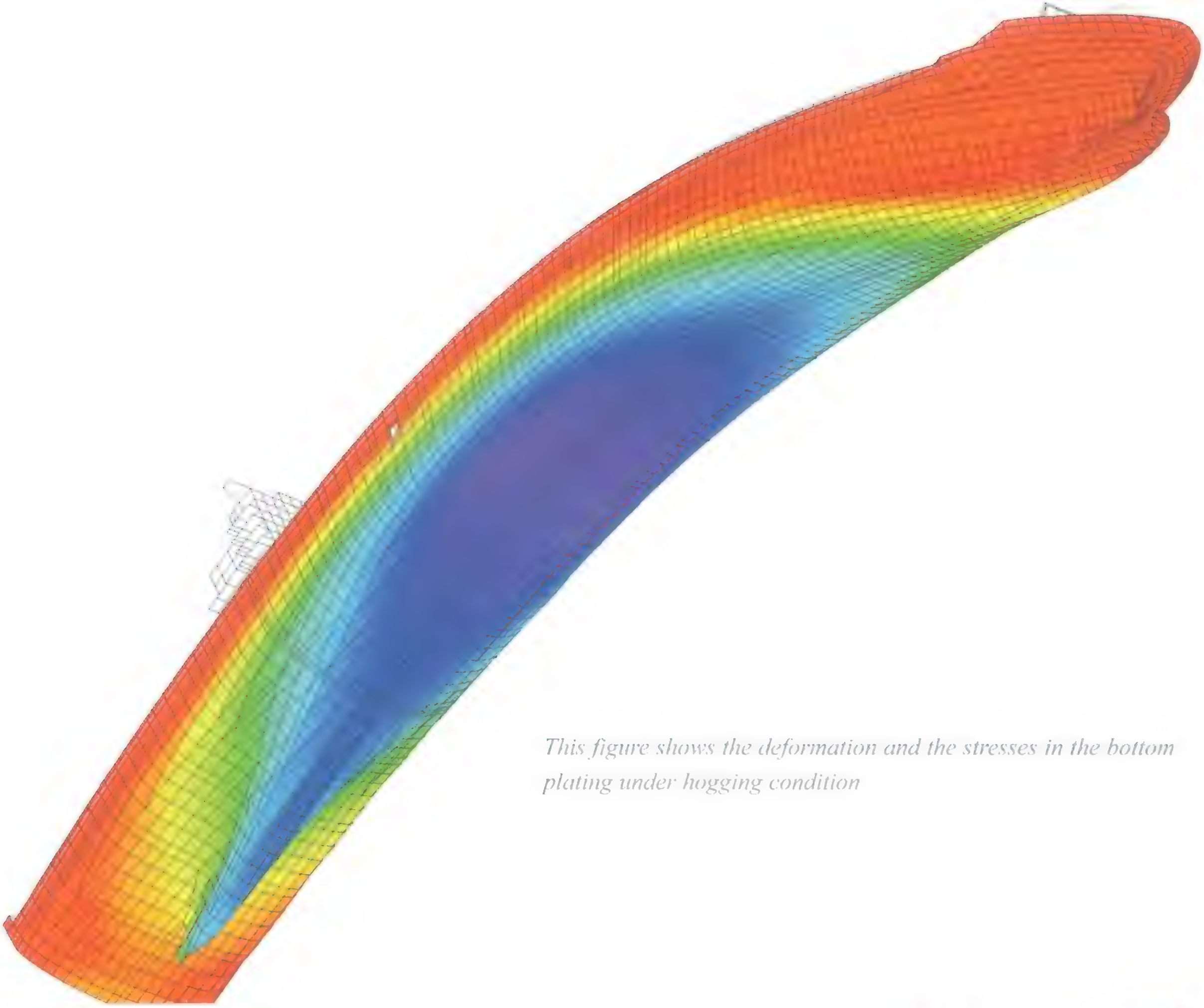
This technique, with the various speeds and wave-patterns, in relation to the ship, simulated in a computer, is a tool for ship managers giving instructions - when to change course or slow down - to ship masters, in order to prevent damages. These computer simulation outcomes can be translated into clear written instructions.



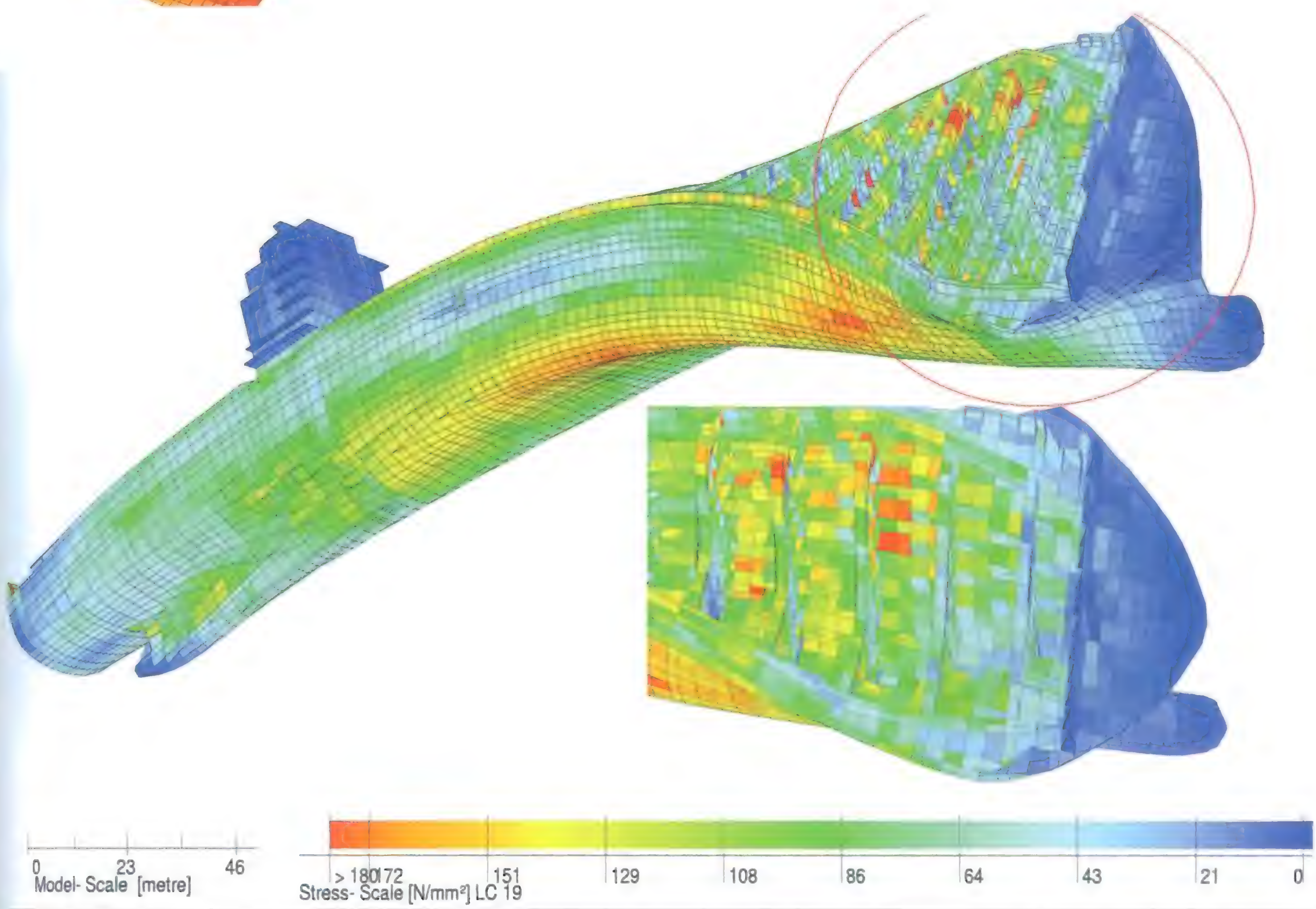
This figure shows the deformation of a large Post-Pana-Max Container vessel in hogging condition.



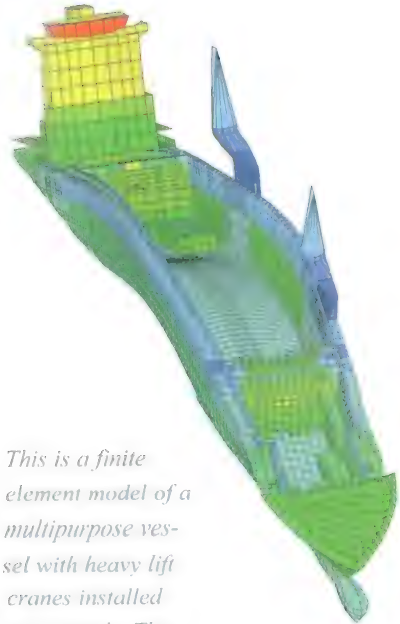
This figure shows the pressure distribution for the above load case.



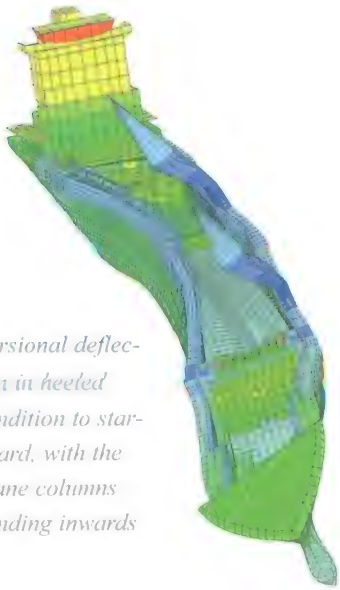
This figure shows the deformation and the stresses in the bottom plating under hogging condition



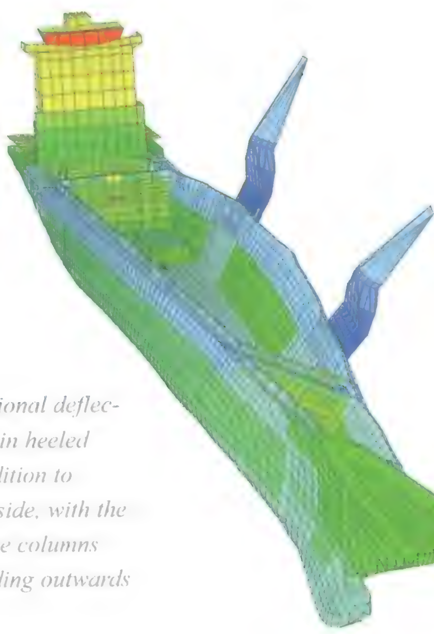
This figure shows the torsional deflection of the same container vessel together with the stresses. Here the detail view into the forward cargo hold is of special interest. The torsional loads cause a considerably high stress level in the partial stringer decks at the positions of changing width.



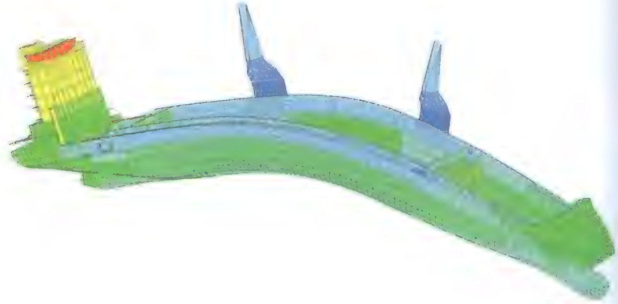
This is a finite element model of a multipurpose vessel with heavy lift cranes installed at port side. The deflections are caused by an oblique sea



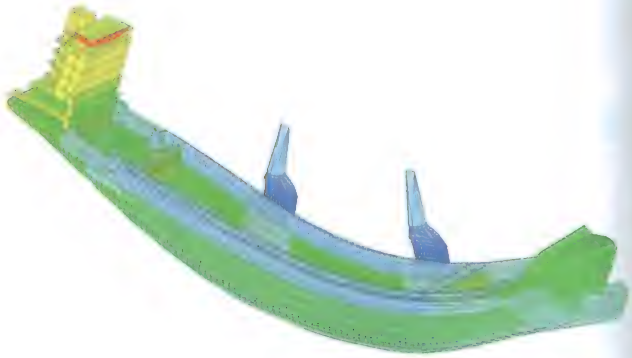
Torsional deflection in heeled condition to starboard, with the crane columns bending inwards



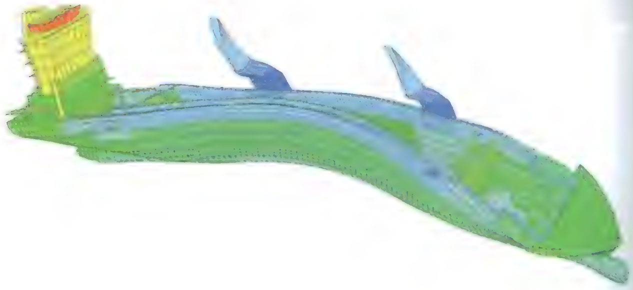
Torsional deflection in heeled condition to portside, with the crane columns bending outwards



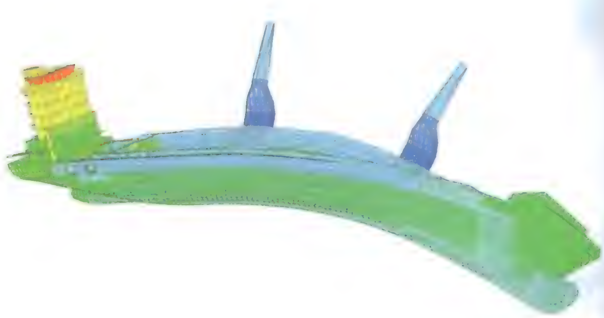
View of left load case from side



Same as above. Deflections in sagging condition. No stress distribution. The different colors represent the plate thickness



View of left middle case load from side



View of the left load case from side

3 Torsion of the Hull

Torsion occurs in a seaway and when there is an asymmetry in the mass distribution over the horizontal plane. For example, if there is a weight of 100 tons on the starboard side of the fore ship which is compensated by an equivalent weight on the port side of the aft ship, there will be torsion (or torque). If both weights are 10 meters from the centreline, the torsion moment will be:

100 ton x 10 meters = 1000 tm.

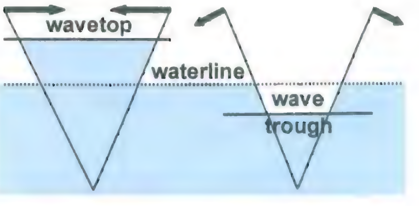
In adverse weather, especially when the waves come in at an angle, the torsion can increase as a consequence of the asymmetric distribution of the upward pressure exerted by the water on the submerged part of the hull. Torsion causes a ship to be subject to extra stresses and deformations. This can result in leaking hatches and defects in **hatch-coaming corners**. Especially "open ships", i.e. ships with large deck openings, tend to be torsionally weak and are sensitive to this. A good example are container ships and modern box-hold general cargo ships. Large bulk carriers (capesize) with large hatch openings and enormous torsional forces when ocean-waves approach at an angle, are specially strengthened in hatch coaming corners.

Damage caused by panting strain. Entire forepeak tank torn off. Ship size 100,000 ton deadweight.

4 Local Stresses

4.1 Panting Stresses

These occur in the fore-ship during pitching. The constantly changing water pressure increases the stress in the skin and frames. Panting stress is not a result of hydrostatic pressure, but a result of hydrodynamic pressure. To reduce the panting stress effect, panting beams in transverse direction and stringers against the ship's shell are added to the forepeak, the area aft of the forepeak and aft peak structure.



Forces on the fore-ship if the ship is on a wave top (left) and in a trough(right).

4.2 Pounding

When pitching becomes so heavy that the entire bow comes above the water, **pounding** or slamming can occur. Especially with a flat fore-ship, such as in bulk carriers and tankers, the dynamic forces on the flat bottom, can result in damage to plating and internals.
To prevent this kind of damage, thicker plates and more internals, are inserted at smaller intervals, such as floors at every frame and more keelsons.

4.3 Diagonal Loads

These occur when the ship is asymmetrically laden and during rolling of the ship in waves. The effect of the diagonal loads is reduced by the addition of frame brackets, deck beam brackets, cross frames and transverse bulkheads.

4.4 Vibration Stresses

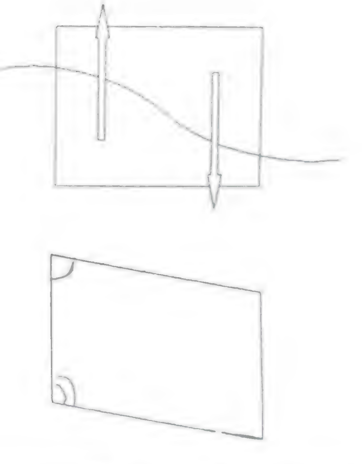
These can be caused by:
- vibrations induced by the (main) engine,
- forces on the aft ship caused by the rotation of the propeller.
- wave impact

Vibration occurs when resonance frequency is equal to the first, second or third order of an induction source: the main engine, the propeller, etc. Adding weight and structure, and so changing the resonance frequency or local stiffening are remedies. Vibration is a growing concern, as ships are being built lighter and lighter, due to the use of high tensile steel, which allows thinner construction at the same strength, and the application of better paints, which eliminates the need of corrosion surplus. Vibration can result in fatigue-defects, noise, and discomfort for the crew.
Vibration can also be eliminated by inducing another vibration source, with contra-pulses.

4.5 Dry docking Loads

These forces are the result of vertical upward forces to the keel and (to a lesser extent) side blocks.

Keel blocks are supposed to take the total weight of the ship. Side blocks are put in dry dock to keep the ship upright, but also to take weight. When calculating block loads, only the keel blocks are taken into consideration.

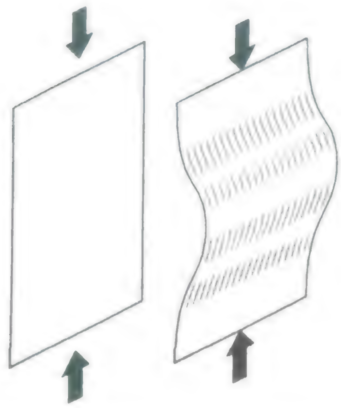


Diagonal loads due to rolling in waves

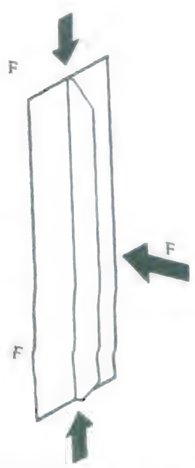
5 Stiffening

5.1 Purpose of Stiffeners

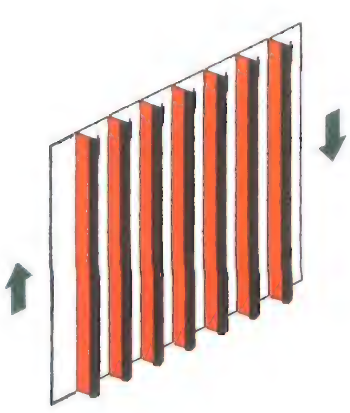
To prevent the plate areas (or plate fields) of a ship from distorting under influence of the shearing loads, bending moments and local loads, it has to be stiffened.



Compressing forces on a plate result in plate buckling.



Compression forces on a stiffened plate. Buckling requires extra force.



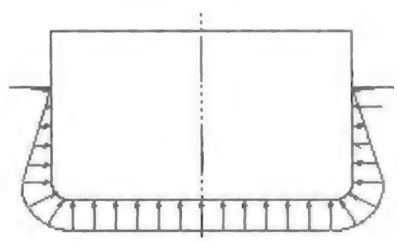
Parallel frames on a plate subjected to bending moment

Examples of plate areas are the shell, decks, bulkheads and tank top.

Deformation of plate areas can be prevented by welding of **stiffeners** (in the direction of the forces).

5.2 Shell plating

The shell plating's primary task is to keep the (sea) water outside the ship. On the outside of the shell there is water and on the inside air, water, fuel or cargo. Difference in pressure outside and inside results, and the shell plating has to withstand bending forces.
The pressure at the shell from outside depends on the draft and varies with the water depth.
The distribution of pressure can be seen in the drawing.

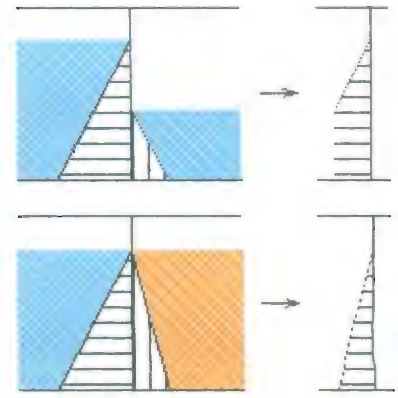


5.3 Decks

The weather deck will deflect under the load of water-on-deck, ice or deck cargo. The tweendeck by the weight of the cargo on deck and to fore, by the apparent increase of weight due to pitching and rolling.

5.4 Bulkheads

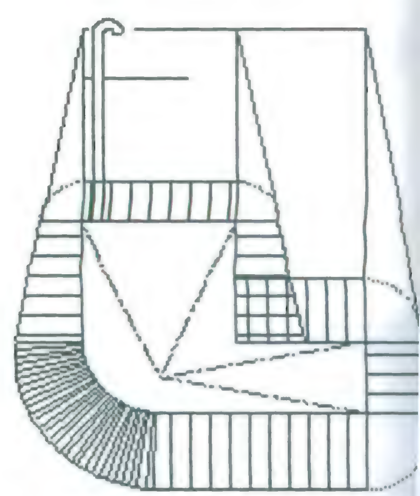
Bulkheads have to withstand bending forces when they border a tank or a hold with bulk cargo. When the contents of liquid or bulk cargo is different in height on either side of the bulkhead, this will result in a pressure difference, causing bending of the bulkhead. At sea, these forces can be multiplied by the ship's movement and the resulting sloshing. For the strength calculation of this kind of bulkhead it is assumed that one side is empty, while the other side is filled with liquid to the height of the overflow pipe on deck.
When a bulkhead also has to function as a support of heavy deck constructions, there are also compression



forces. Bulkheads fitted against torsion of the hull have to be stiffened keeping diagonal forces in mind.

5.5 Tank top

The tank top, the closing plate of the double bottom, can be under pressure from below from liquids and above from cargo resting on it. Pressure from underneath is caused by liquid in the double-bottom tank, and the height of the overflow / air pipes which allow the liquid to fill high in the pipe, or even to overflow. The height of the liquid column causes pressure on the tank top. See drawing.



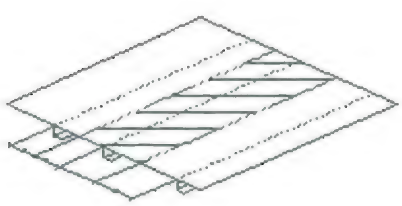
5.6 Panel

The water pressure results in forces on the plating, which are so large that they cannot be absorbed by the plate without deformation or even fracturing. Therefore, the plates have to be stiffened by stiffening profiles. A combination of plate with stiffeners is called a panel.
By adding stiffeners, the panel is divided in strakes, the width of the stiffener-spacing. The load on that area is transferred to the stiffener, which in itself has gained in strength

due to the fact that it is welded to the plate. The thickness of the plating is determined by the stiffener spacing. In bulkheads, therefore, the lower plates are thicker than the upper plates. Classification provides regulations for the maximum spacing of stiffeners, depending on their function (shell frames).

Each stiffener takes a part of the total force working on a panel. The magnitude of the force is related to the pressure on the panel, the spacing of the stiffeners and the (unsupported) length of the stiffener. The drawing below shows the part supported by the middle stiffener.

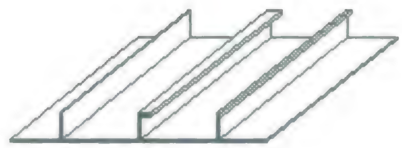
To determine the dimensions of the stiffener, a percentage of the width of the plate carried by the stiffener, is taken into the calculation of the required section modules. The section modulus comprises stiffener plus plate. The effective part of the plate is called the contributing plate.



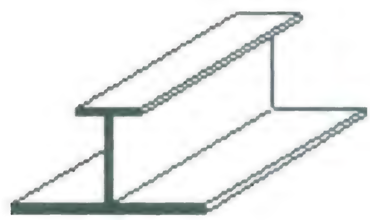
When the unsupported length (span) of a stiffener is so long that it results in very heavy stiffeners, the stiffeners themselves get support from even heavier stiffeners, the so-called **stringers** or **web frames**.
The table shows various panels with their specific stiffeners and supporting webs.

The spacing of horizontal webs and stringers (flats), increases from a small spacing at the bottom to a large spacing at the top of the bulkhead, in connection with the triangular liquid pressure on the bulkhead.

The same (vertical) profile section over the full height of the bulkhead is then used.

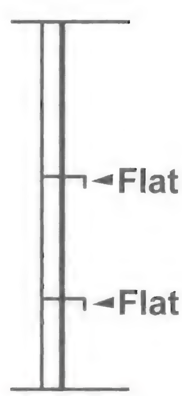


Stiffeners can be chosen from a range of types. The most commonly used are flat bars, inverted angle bars and Holland-Profiles or bulb-flats. These are hot-rolled sections.



Constructed T-profile

Web frames and stringers can be made of similar profiles, but this is impracticable. Normally these beams are constructed from plate with a flange or facebar.



5.7 Longitudinal Framing and Transverse Framing System

Longitudinal forces are present on all ships and play a larger role if the ship is longer and/or has less depth. This is why ships with a length of more than 70 meters are usually constructed in accordance with a **longitudinal stiffening system**. This means that the primary stiffening of the shell plating, deck and bottom plating run fore and aft.
Ships shorter than 70 meters (for example fishing boats and tug boats) are usually built in accordance with a **transverse stiffening system.** The decision to use either longitudinal or transverse framing is also influenced by the shape. If the parallel mid body is relatively long, for instance in ships for inland navigation and in barges, longitudinal stiffening is cheaper and easier. This is also true with shorter ships.

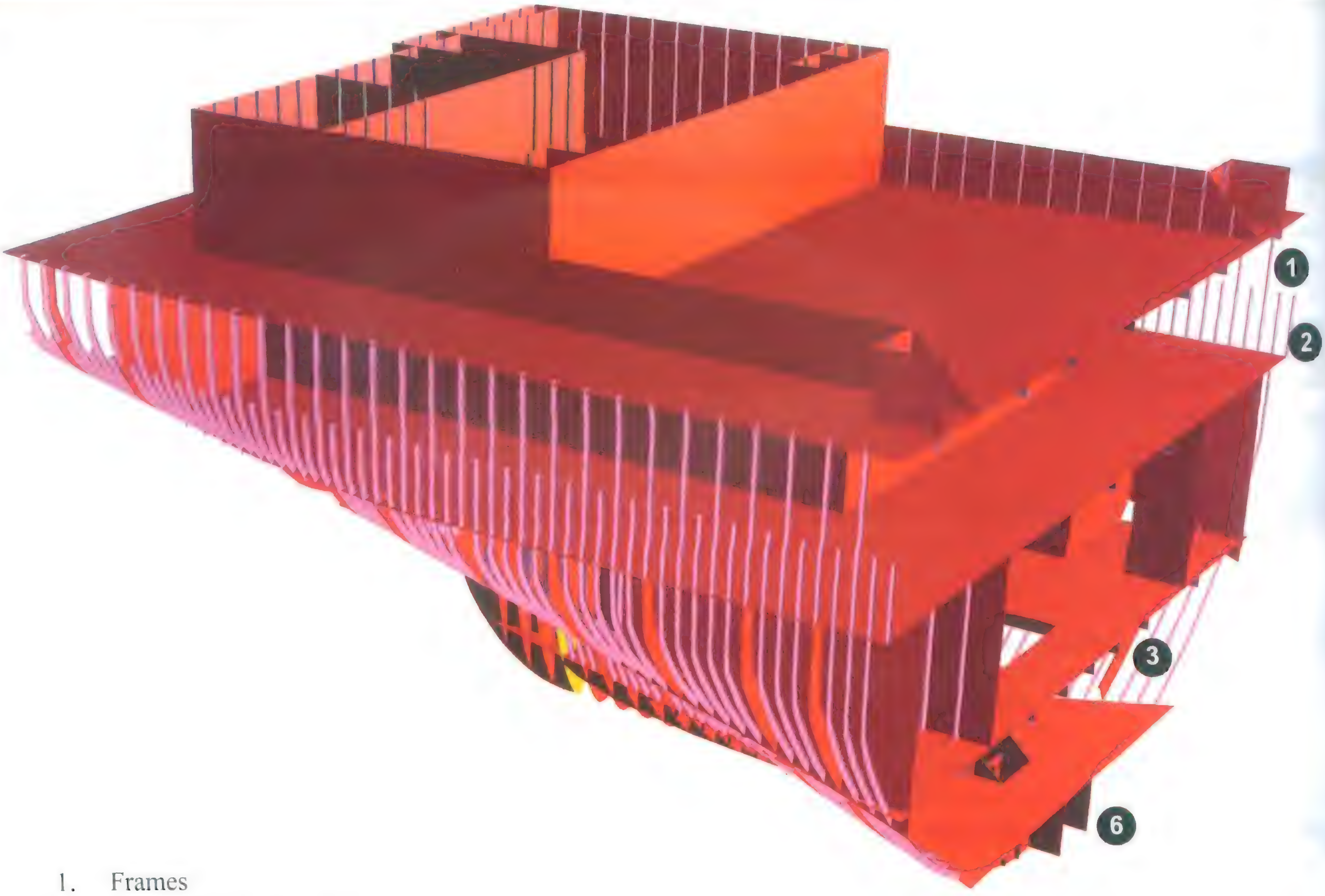
Lloyd's Register does not require a calculation for longitudinal strength if the ship is shorter than 65 meters.

The next four pages portray different kinds of ships. First, the aft ship of a container vessel with transverse framing, then a double hull tanker built with the longitudinal framing system and thirdly, a tug boat with transverse frames.

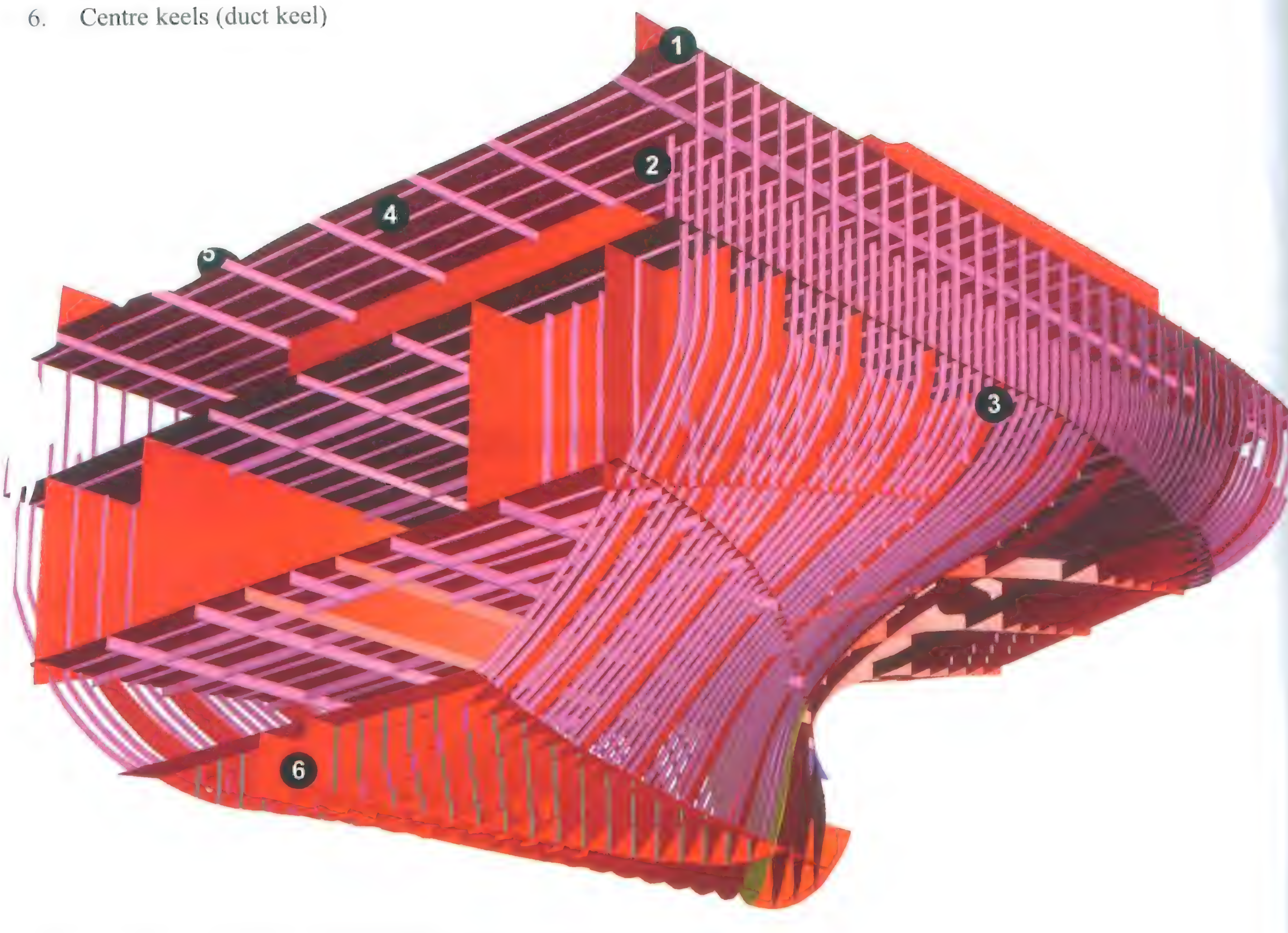
Similar stiffeners have names in connection with the type of panel they support.

Planes:	Stiffening:	Support:
shell	(vertical) frames (horizontal) longitudinals	stringers (horizontal) web frames
bulkheads	horizontal stiffening vertical stiffening	stringers (horizontal) web girders
decks	deck beam or longitudinals	deck girders or deep beams
flat bottom	bottom longitudinals (fore and aft) bottom frames (transverse)	floors keelsons
tank top	upper frames (fore and aft) upper frames (transverse)	floors keelsons

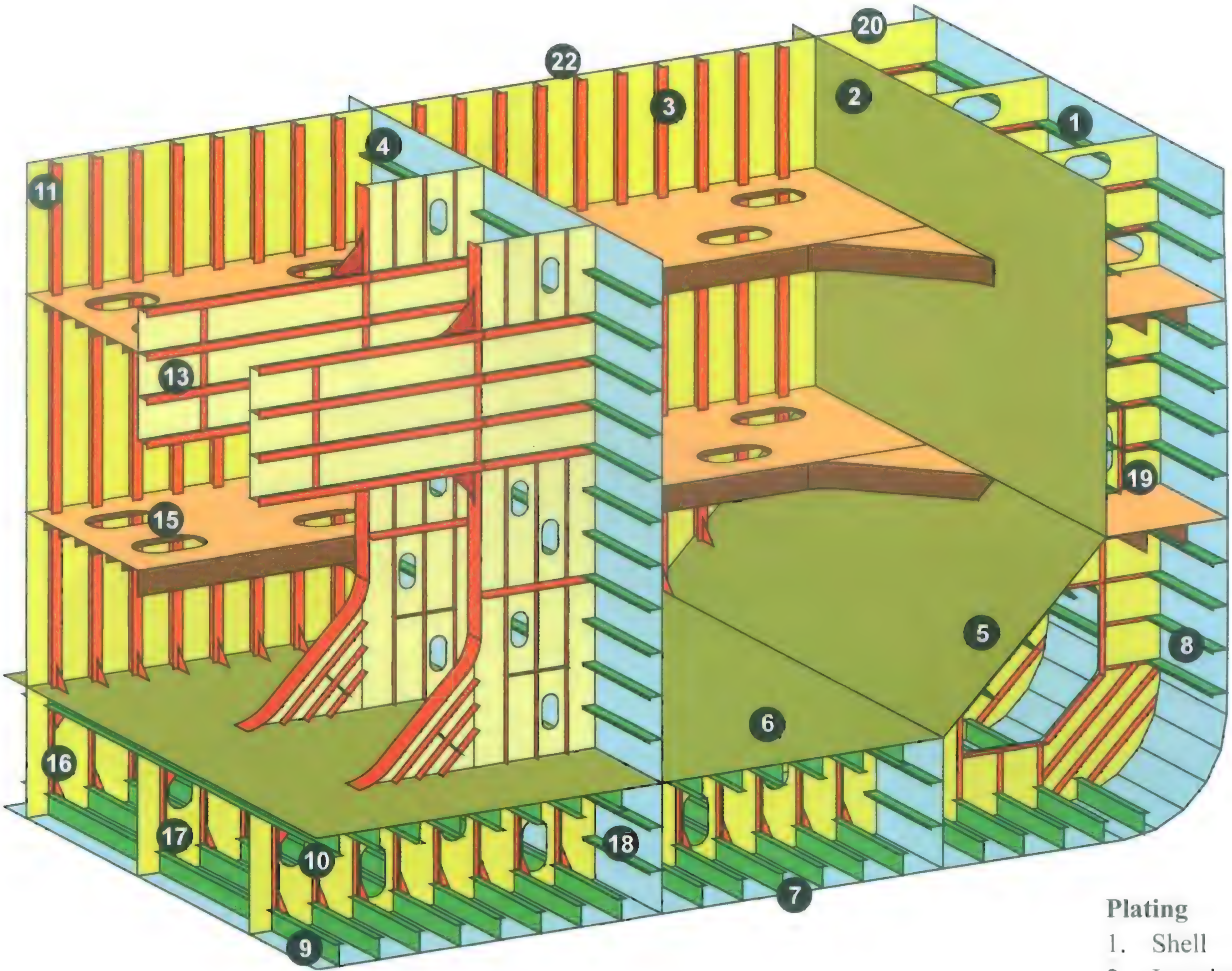
Similar stiffeners have different names for different planes

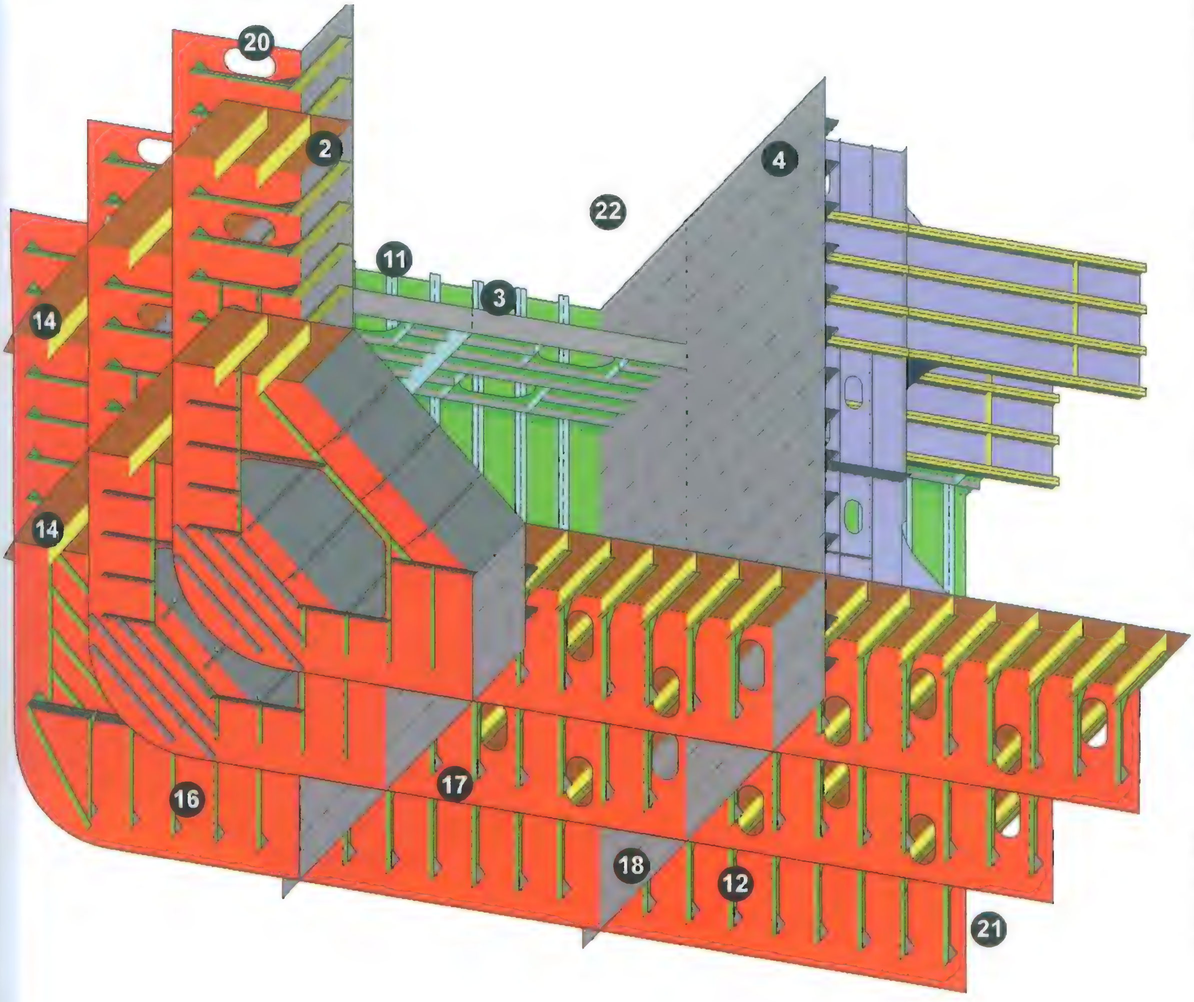


1. Frames
2. Ice strengthening frames
3. Web frames
4. Deck beams
5. Deck girders
6. Centre keels (duct keel)



Cross-section of a container ship near the engine room. (transverse frames)





Plating
1. Shell
2. Longitudinal bulkhead (of the inner hull)
3. Transverse bulkhead
4. Longitudinal bulkhead
5. Lower hopper
6. Tank top
7. Bottom

Stiffeners on the plating

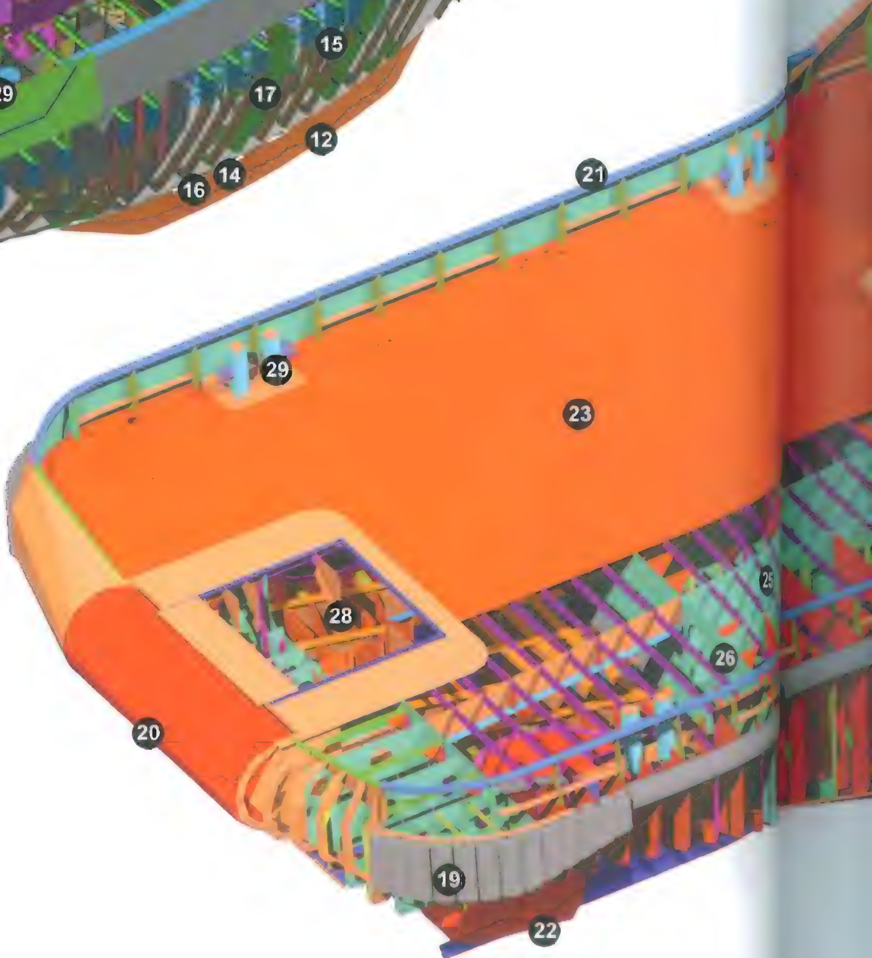
8. Side longitudinals
9. Bottom frame / Longitudinal
10. Inner bottom longitudinal
11. Bulkhead stiffener
12. Stiffener with brackets

Plate-stiffeners

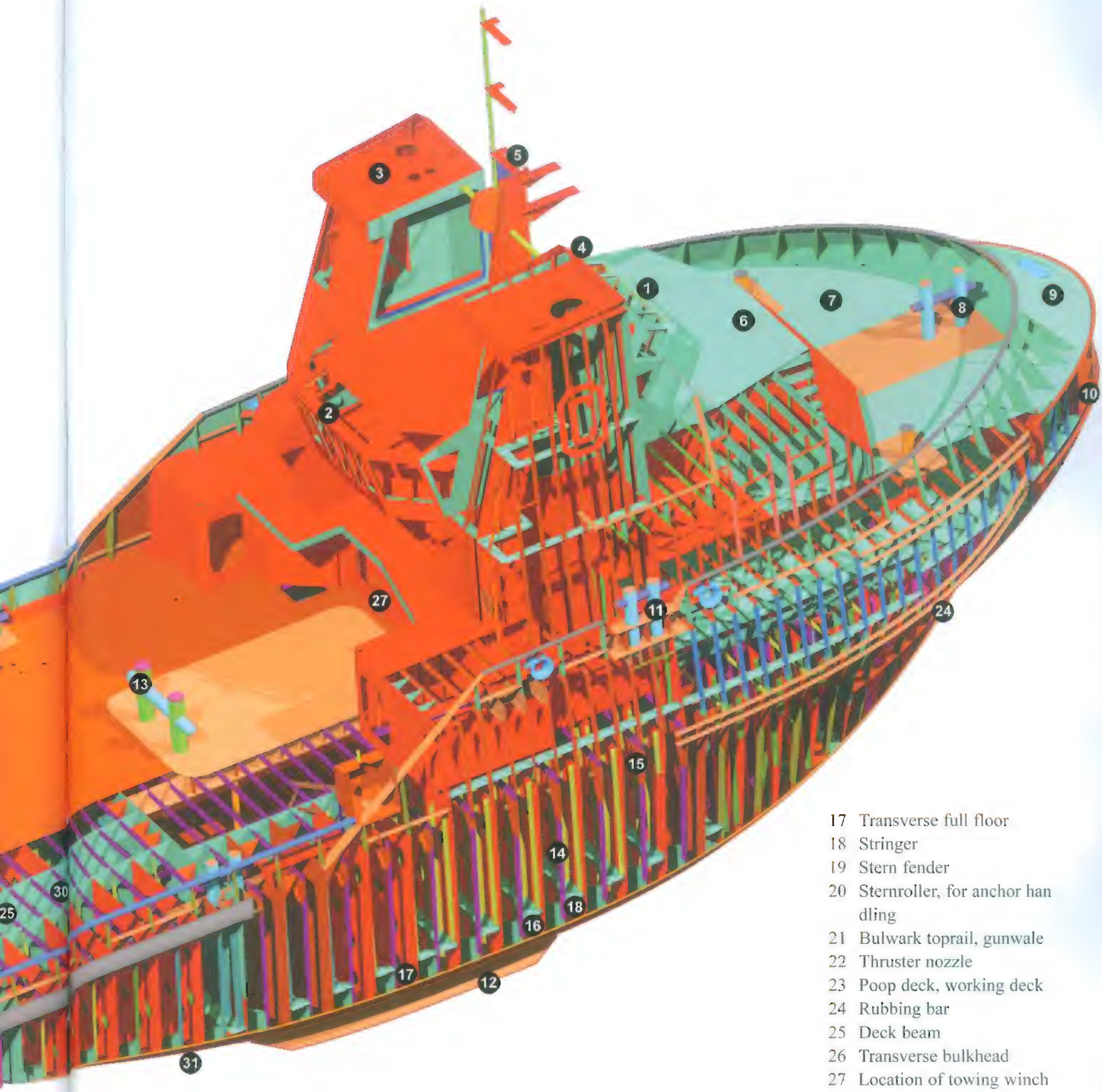
13 Tie beam or cross-tie
14. Stringer
15. Stringer deck
16. Watertight floor
17. Plate floor
18. Watertight side girder
19. Web frame

Holds

20. Wing ballast tank
21. Double bottom
22. Cargo tank



1 Wheelhouse front windows
2 Wheelhouse rear windows
3 Portside funnel
4 Starboard side funnel
5 Mast
6 Deckhouse top
7 Foredeck
8 Forward bitts
9 Forward bulwark with closed clock
10 Location bow fender
11 Side bollard forward
12 Bilge keel
13 Towing bitt
14 Sideshell transverse frame
15 Deck bracket
16 Bilge bracket

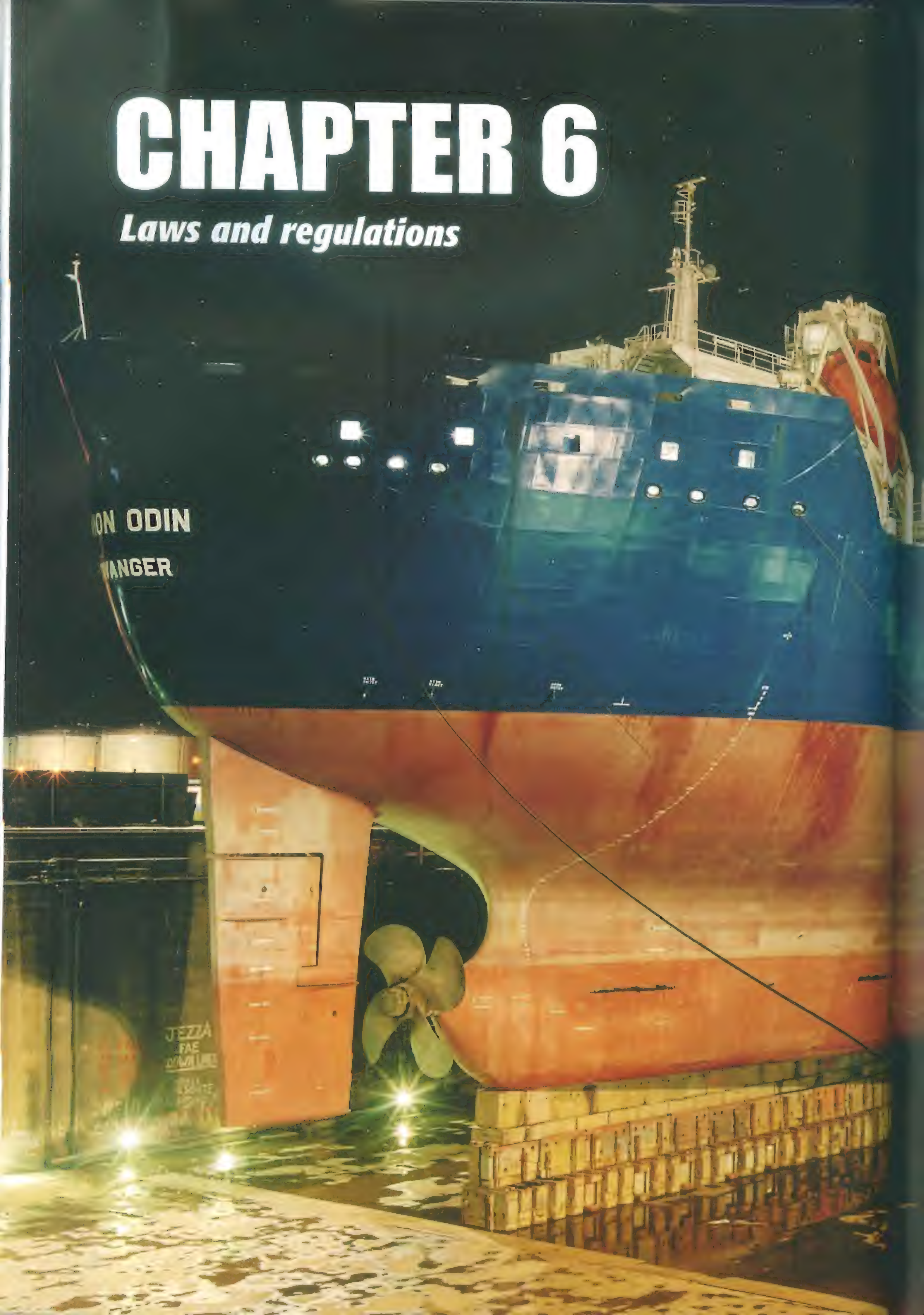


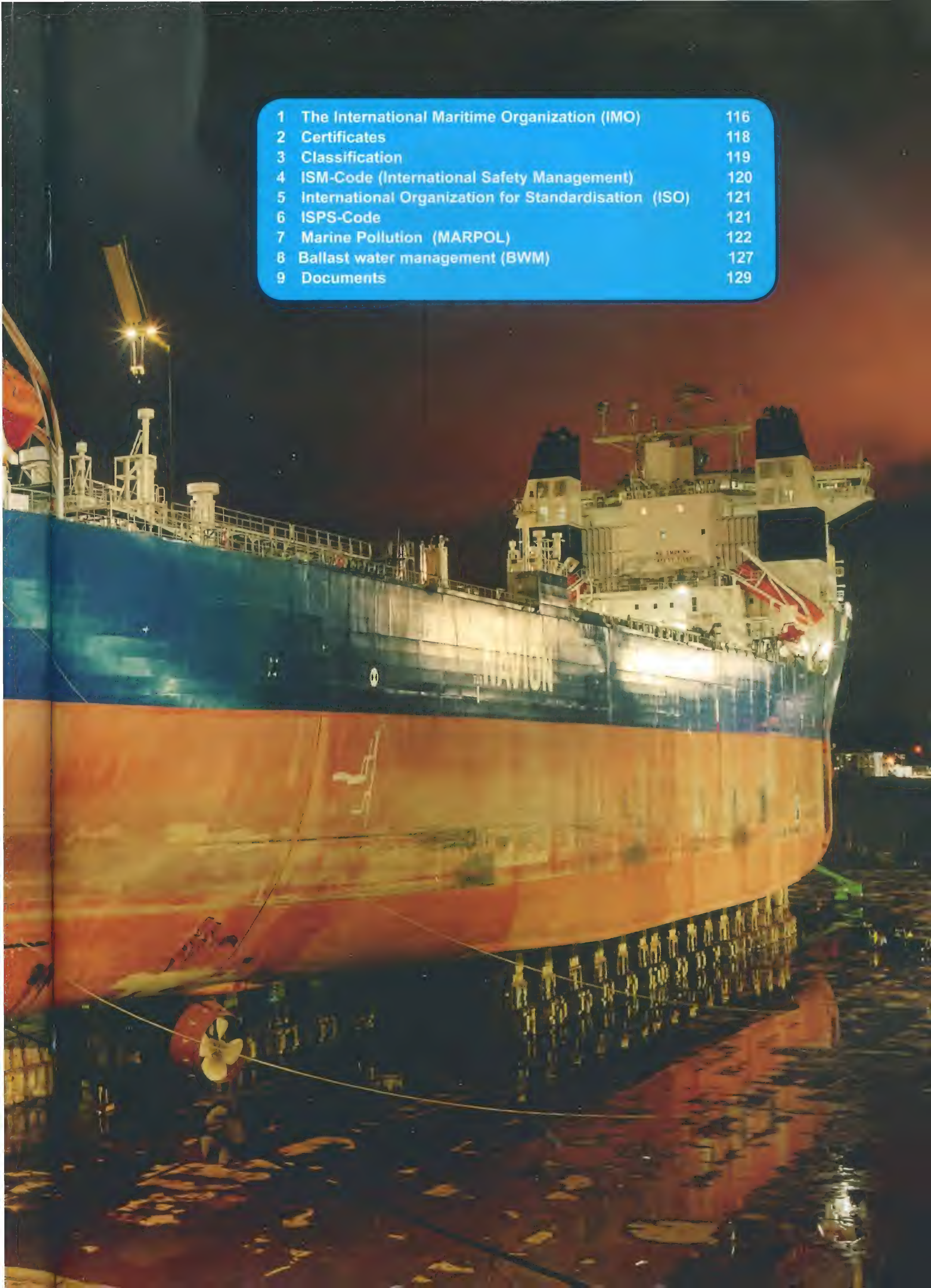
17 Transverse full floor
18 Stringer
19 Stern fender
20 Sternroller, for anchor han dling
21 Bulwark toprail, gunwale
22 Thruster nozzle
23 Poop deck, working deck
24 Rubbing bar
25 Deck beam
26 Transverse bulkhead
27 Location of towing winch
28 Steering-gear room
29 Side bollard aft
30 Longitudinal bulkhead (Shaft tunnel)
31 Bilge plating

Bender Shipbuilding & Repair Co., Inc.

CHAPTER 6

Laws and regulations





NAVION

1. The International Maritime Organization (IMO)

1.1 General

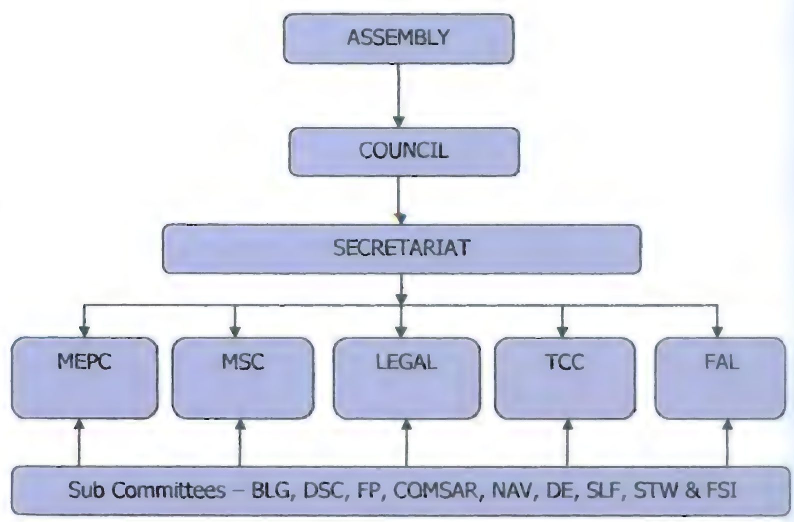
International shipping, and national shipping to a lesser extent, are subject to stringent **laws and regulations**, by international and national regulatory bodies. These bodies are united in the International Maritime Organization, IMO, which falls under the United Nations.

The main objective, from the first conference in 1948 up to its implementation in 1958, is improvement of safety at sea. **SOLAS** (Safety **O**f **L**ife **A**t **S**ea) goes back as far as 1914, but due to World War I, never came into force. There were even earlier international treaties, but they were not very successful.

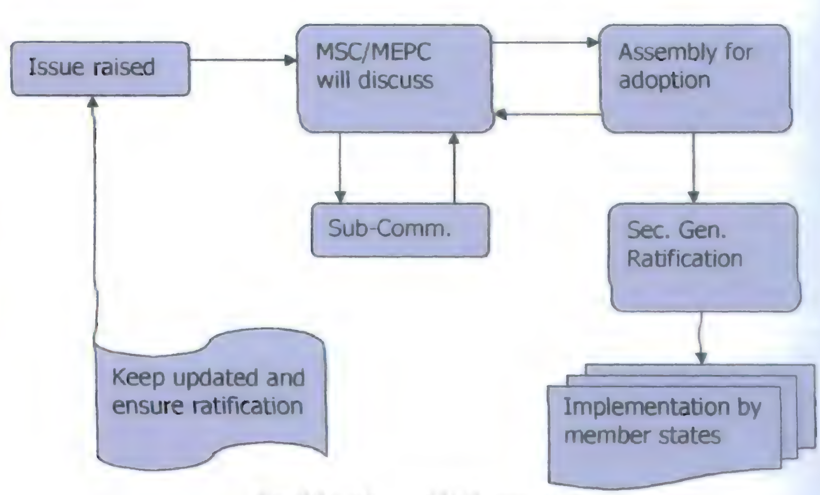
Seafaring has, throughout history, always been one of the most dangerous occupations. Many countries had unilateral regulations on safety, but as sea trade is of an international nature, the rules and regulations needed to be international.

The slogan is: **Safe, Secure and Efficient Shipping on Clean Oceans**

The first objective was to improve safety of life at sea, **SOLAS**, followed by concern for marine pollution, resulting in the **MARPOL-Convention**, accelerated by the Torrey Canyon accident (1967).



Basic structure of IMO



Brief flowchart of IMO processes

1.2 Assembly / Committees

Within IMO the governing body is the **Assembly**, which has installed **Com-mittees** for the different objectives.

- **MSC**, the Marine Safety Committee, with safety related Conventions and Codes, resulted in the SOLAS Convention.
- **MEPC**, the Marine Environment Protection Committee, resulted in the Marpol regulations, first in 1973, and later in 1978.

Other Committees are LEGAL (Security), TCC (Training) and FAL (Electricity).
There are some 10 sub-committees.
As of September 2007 there were 166 member states.

Through the years many conventions, protocols, codes and amendments have been adopted. After adoption, individual governments must ratify the protocols or conventions. Depending on acceptance by the number of governments and the gross tonnage governed by them, a Convention comes into force.
It is followed by the implementation, when the new regulation becomes law under the responsibility of the **flagstate**. The whole process can take many years.

Port State Control:
In 1978 flagstates around the North-Atlantic and in the Mediterranean set up a system of ship inspections related to the international regulations regarding Loadline, SOLAS, Marpol, Tonnage, Colreg, Living and working conditions of crew, Dangerous Goods, Class, etc.
The target is to inspect 25% of the ships coming to their ports. In case deficiencies are found, they normally have to be rectified before departure, or are to be checked in the next port. Important deficiencies result in the ship's detention, which means that the ship is not allowed to depart before the deficiencies are corrected.

Designed, approved and surveyed to withstand the roughest seas.

1.3 Conventions and Codes

The Conventions and Codes result in certificates worldwide recognized which ships have to carry after being surveyed to ensure that they meet the requirements, for that particular ship. A variety of compulsory equipment has to be type-approved by flagstate(s) and/or Classification Society.

The following IMO Conventions have been adopted
(not all have been implemented):

- The International Convention on **Load Lines 1966**
- The International Convention for the **Safety of Life at Sea,** SOLAS '74, '88
- The International Convention on Standards of Training and Certification of Watchkeeping for Seafarers (**STCW**)
- The Convention on the International Regulations for Preventing **Collisions** at Sea, (**Colregs**)
- The International Convention on **Tonnage** Measurement,
- The International Convention for the Prevention of **Pollution** from ships, 1973, modified as per Protocol 1978 (Marpol)
- The International Convention on the Control of Harmful **Anti-Fouling** Systems
- The International Convention for the Control and Management of Ship's **Ballast water** and Sediments
- The International Convention on the **Safety of Fishing Vessels**

Each of the Conventions is, where necessary, more detailed in **Codes**. However, some Codes are independent of a Convention.

Examples of CODES:

- The IMO Code for the Construction and the Equipment of Ships Carrying Dangerous Chemicals in Bulk,
- The ILO/IMO Code of Practice on Security in Ports
- The IMO Code of Safe Practice for Solid Bulk Cargoes (BS Code)
- The International Safety Management Code (ISM)
- The IMO Code of Safe Practice for Ships Carrying Liquefied Gases in Bulk
- The FAO/ILO/IMO Code of Safety for Fishermen
- The IMO Code of Safe Practice for Cargo Stowage
- The IMO Code of Practice for Atmospheric Oil Mist Detectors
- The IMO Code of Practice for the Safe Carriage of Irradiated Nuclear Fuel
- The IMO International Code of Signals
- The IMO Code of Equipment of Mobile Offshore Drilling Units (the MODU Code)
- The IMO Fire Safety Code
- The IMO Life Saving Code

Flagstate:
Flagstate is the country in which the ship is registered. Each country is responsible for the laws and rules applicable to ships sailing under their flag. Often the control of the rules is delegated to the Classification Society of the relevant ship.

2. Certificates

Before any Certificate can be issued, a ship must be registered in a certain country, the **flagstate**. This means that the flagstate allows a ship to carry its flag and belong to its 'fleet'. For a certain fee, and taxation on the earnings, the authorities allow the ship to sail under their jurisdiction. The port and country where the ship has been registered has to be marked on the stern.

The certificates can be divided into certificates every ship must have on board, certificates which are connected to the type of cargo the ship is intended for or the area the ship is allowed to sail.

2.1 Compulsory Certificates in accordance with SOLAS

The SOLAS Convention requires **every** ship (above 500 GT) on international voyages to have on board:

Cargo ships:
- Cargo Ship Safety Construction Certificate
- Cargo Ship Safety Equipment Certificate
- Cargo Ship Safety Radio Cert.

A **Cargo Ship Safety Certificate**, is a combination of the above certificates and can be issued to replace individual certificates. The certificates have to be accompanied by a **Record of Equipment**, a list of items which need to be on board the relevant ship.

SOLAS regulated the ship's construction, with regard to strength, maximum size of floodable compartments, intact and damage stability, covered under the **Safety Construction Certificate**.

Passenger ships:
Passenger Ship Safety Certificate

This certificate has been in use longer than the cargo ship safety certificate, and has the same content.
Rules and regulations and certificates are more stringent for passenger ships than for cargo ships.

2.2 Certificates, compulsory in accordance with other Conventions:

2.2.1 Loadline

The Loadline Convention requires the **International Loadline Certificate**, which is evidence of meeting freeboard requirements, as prescribed in the Convention, and in the relevant Code. Loadline requirements were initiated in the United Kingdom by a member of parliament, Mr Plimsoll. Since 1876 certificates have been issued by the Classification Societies, when the Freeboard Mark or Plimsoll Mark became compulsory. The regulations are laid down in the 1966 Loadline Convention. On the basis of a ship's length, size of openings on deck, sheer, doorsill heights, etc., a minimum freeboard is calculated and has to be displayed at the ship's side. The regulations regarding carriage of timber as deck-cargo, or oil in an oil tanker, are more relaxed. The Plimsoll Mark is a safety mark showing minimum freeboard.

2.2.2 Tonnage

The Tonnage Convention requires every ship to be provided with **The International Tonnage Certificate.** As proof of registration, the Flagstate or the Classification Society issues this certificate. This certificate is accepted worldwide and provides the official details of the ship: main dimensions and volumes of the various spaces, in particular the spaces in connection with cargo, cargo holds, tanks, etc., all in accordance with regulations set out in the Tonnage Convention.
It shows **Gross Tonnage** and **Net Tonnage,** figures with a legal implications. Net Tonnage is the Gross Tonnage minus the spaces which do not directly contribute to the earnings, such as ballasttanks and the engine room for a certain percentage. Details can be found in the Convention. Harbor dues and many other financial charges are often based on GT.
Every ship is provided with a so-called **IMO number,** a 7-digit identification number, the idea for the number borrowed from Lloyd's Register. The number stays with the ship for its lifetime has to be clearly visible and is printed on all certificates.

Survey to verify freeboard marks on side of ship.

Inspecting a hatch on a life boat for compliance with the latest regulations.

Surveyors check links and shackles of an anchor chain.

In a manufacturer's workshop a local surveyor reviews the fit-up and alignment of intermediate and thrust shafts.

Apart from the International Tonnage Certificate, the **Suez Canal** and the **Panama Canal** have their own 'tonnage' requirements on which their fees are based. Therefore, special tonnage certificates are issued for Suez Canal and Panama Canal.

2.2.3 Marpol

The Marpol Convention requires, under Annex I, a valid **International Oil Pollution Prevention Certificate (IOPP),** which must be carried on board.
Oil tankers and other cargo ships of 400 GT and above have to be provided with the International Oil Pollution Prevention Certificate. (See under 7).

Marpol contains **Annexes,** such as:
- Annex I above,
- Annex II regulates liquid chemical cargo in bulk, in the **Certificate of Fitness**,
- Annex III, dealing with Harmful Substances in packed form, is the certificate for **Dangerous Goods**,
- Annex IV deals with **Sewage**,
- Annex V, deals with **Garbage**,
- Annex VI deals with air pollution.

2.3 Examples of Certificates in connection with the ship's designation:

2.3.1 Dangerous Goods

International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk (IBC Code Certificate), accompanied by a Cargo list, is issued when the ship complies with the regulations in the relevant Code. A chemical tanker has to carry equipment to minimize residues in cargo tanks and various measurement tools and special equipment related to the cargo they transport. The cargo list gives the names of the chemicals the tanks are suitable for. This relates to closing appliances, cargo tank coating, gasket materials, protective clothing, breathing apparatus, gasmasks, etc.

2.3.2 Certificate of Fitness for the Carriage of Liquefied Gases in Bulk

Gas ships carry this certificate, in accordance with the International Gas Code, or for older ships, the Gas Carrier Code.

2.3.3 Certificate of Compliance for the Carriage of Dangerous Goods

The carriage of dangerous goods in all forms: packaged form, in solid form in bulk, explosives, dangerous liquid chemical cargoes in bulk in chemical tankers, gases in gas-tankers and packed radio active materials, is regulated in SOLAS Chapter VII. In subdivisions A-D all kinds of rules and provisions govern the ship's construction, stowage and packing, labeling, etc.

The certificate clearly states which dangerous goods the ship is allowed to carry. An approved cargo list gives the specific names.

2.3.4 Certificate of Compliance for the Carriage of Solid Bulk Cargoes

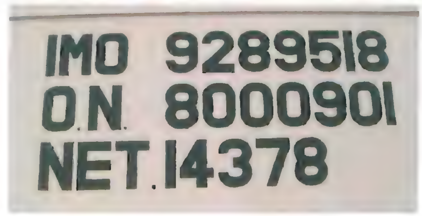
A special certificate has been created for the transport of Solid Bulk Cargoes on bulk carriers. These cargoes have been categorized A, B and C, depending on their hazards. A is the least harmful, C the most harmful. For each of these cargoes there are special requirements.

2.3.5 Minimum Safe Manning Certificate

The flagstate is also responsible for stating the minimum number of crew, and their required qualifications.

3. Classification

Ships are built in accordance with Rules and Regulations of a Classification Society, chosen by the prospective owner. The Society approves the relevant drawings and inspects the actual construction. Classification contros strength and quality of materials and workmanship in connection with the ship, when built "under Class".
The Classification Society issues a certificate upon completion of construction:
The Certificate of Class, for Hull and Machinery.
The Certificate of Class is the basis for underwriters to insure a ship.
A trading Certificate of Class is issued with a validity of 5 years, to be endorsed every year upon completion of the **Annual Survey**.



O.N.: Official Number
NET.: Net Tonnage

Every year, in a window of three months before the birthday and three months after, an **Annual Survey** has to be carried out, covering Class, Safety Construction, Safety Equipment, Loadline, Radio, Marpol, Fitness, Dangerous Goods, Cargo-gear, etc. Normally all are done at the same port of call.

If at the end of three months after the 'birthday', one of the **trading certificates** has not been endorsed by the relevant Classification or flagstate the ship is not allowed to leave port.

To carry out the different surveys, the Class Societies each maintain a worldwide network of surveyors.
Since 1968, the main Societies have been grouped under **IACS**, the International Association of Classification Societies. Since 1970 they have served as consultants to IMO, contributing their expert technical knowledge.

Birthday:
The date on which the certificates were first -issued.

For Class and ISM, ships have to dry-dock two times in five years

The members are (in alphabetic order):

- American Bureau of Shipping (ABS)
- Bureau Veritas (BV)
- China Classification Society(CCS)
- Det Norske Veritas (DNV)
- Germanischer Lloyd (GL)
- Korean Registry (KR)
- Lloyd's Register (LR)
- Nippon Kaiji Kyokai (ClassNK), Japan
- Registro Italiana Navale (RINA)
- Russian Maritime Register of Shipping (RS)

Classification is concerned with the safety of the ship and the cargo. The focus of the flagstate is safety of the people on board.

The division between Classification certificates and statutory certificates is as follows:

- the Classification Society looks after the technical condition of the ship
- the flagstate, after the people on board, safety, the environment and communication.

However, many flagstates delegate these tasks to the Classification Society. Therefore, on many ships, the **statutory certificates** are also issued by the Classification Society.

The validity of the certificates have been harmonised since 1999, as per IMO Assembly resolution A.883 (21). All certificates have a validity of five years, starting from the new building date, and are renewed at each Special Survey, i.e. after 5 years. The 'birth-day' remains the same.

4. ISM Code International (Safety Management)

4.1 Introduction

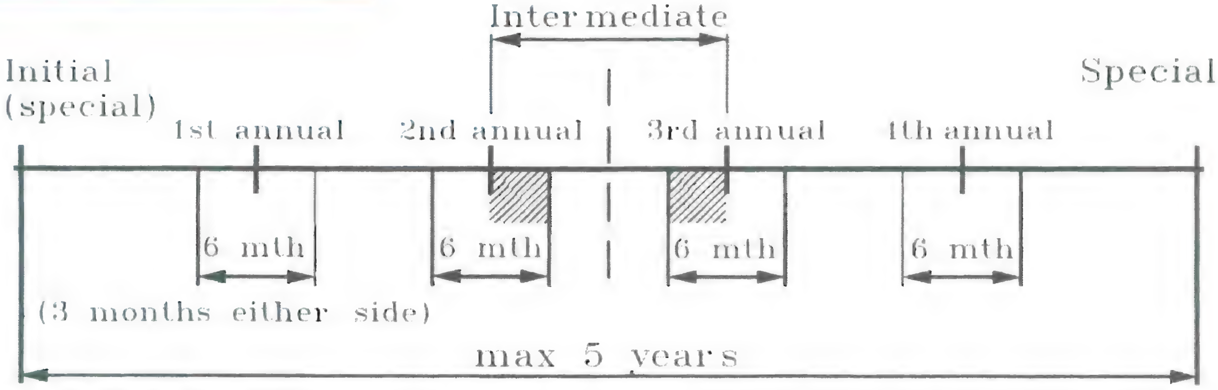
An issue of IMO is the International Safety Management (ISM) code. This certificate, for both ship and office, is a statement that owners/managers and the ship's staff are committed to maintaining the vessel as required, and to fulfill obligations connected with safety and pollution.

Most regulations in shipping concern technical aspects of the ship and the required training of the crew. The **ISM code**, applicable to all ships since 2002, is a list of regulations for the organization of the ship, and the management system.

The management system comprises:

- organization on board ship
- organization ashore
- organization of the shipping company
- communication between shore and ship

The importance of good management for safety in general is illustrated by the fact that **80% of all accidents in shipping are the result of human error.**



Classification Special Survey Cycle

4.2 Objectives

The objectives of the ISM-code are:
- to satisfy all relevant national and international regulations such as SOLAS, MARPOL, ISM, Class and Labor laws
- to create permanent awareness of safe behavior by personnel on board and ashore
- to ensure a readiness to act effectively in emergencies
- to guarantee safety at sea
- to prevent accidents and damage to environment

The ISM-code is a standard of safety consisting of 13 elements, each describing a business operation relevant to safety and environment, such as:
- (planned) maintenance
- office personnel and crew

4.3 How ISM works

a. The Shipping Companies

Every shipping company must possess a **Document of Compliance (DOC)**. This document states that the shipping company is found fit to exploit the ship in accordance with the ISM-code. One of the requirements is that the shipping companies must develop, execute and maintain a **Safety Management System (SMS).**
The flagstate issues the DOC, but only after a Classification Society has approved the safety management system. The DOC remains valid for a period of five years, provided that the annual surveys by the Classification Society yield good results.

b. The Ships

Ships get a **Safety Manage-ment Certificate (SMC)** if the DOC has been issued to the shipping com-pany. The SMC also remains valid for a five year period. During this period there should be an inspection between the second and third year.

4.4 The Audits

The SMS is inspected by means of an audit. An audit is a prescribed survey to check whether the organizations on shore and on the ship are able to successfully execute the regulations and have reached certain goals. Audits can be internal or external.

The ISO-organization grants one certificate to the entire organization, contrary to the ISM which has separate certificates for the organization on and off shore.

a. Internal Audits

Internal audits are performed by the shipping company and handle matters such as:
- actual work practisch relative to the SMS regulations
- safety measures and the environment relative to the SMS efficiency and ability to take appropriate measures

All relevant personnel must be informed of the results of these audits and the measures taken. The management must correct all shortcomings. Internal audits are usually performed annually.

b. External Audits

External audits are performed by the bureau of classification under supervision of the flagstate. If the organisation lives up to the standards set, the shore organization receives the DOC and the ship the SMC.

5. International Organization for Standardization (ISO)

ISO has drawn up the:
- ISO 9000 (standard)
- ISO 14000 (environment)
- ISO 18000 (labor circumstances)

These standards guarantee quality.

ISO standards are voluntary. The company draws up a **Quality Management System (QMS)**, certified by a bureau of classification.

The ISO 9000 standard is a general standard aligned to the ISM code. This means that every company draws up and executes its own QMS based on the requirements.

6. ISPS Code

Measures have been taken in connection with the growing threat of terrorist attacks, by various regulatory bodies.
IMO has compiled regulations under the name:
International Ship and Port Facility Security Code (ISPS Code).
Applicable to:
- Passenger ships
- Tankers
- Ferries
- Cargo ships above 500 GT
- Mobile Offshore Drilling Units
- Harbor facilities and means of transport.

These vessels need to have on board an **International Ship Security Certificate.** Fishing ships and Naval ships are exempted from the Code.

The objective of the ISPS Code is to minimize risk of terrorist activity.
Company Security Officers (CSO) are appointed:
- On a ship the **Ship Security Officer (SSO)**
- For a harbor facility, the **Port Facility Security Officer (PFSO).**

All ships which are obliged to carry an ISPS certificate, and the relevant harbor facilities have to compile a security scheme:
- To know who is on board or in the facility;
- To control entrances and perform visitor identity checks;
- To control loading and discharging cargo and stores.

The ISPS Code acknowledges 3 threat-levels:
- level 1: No specific threat → no additional measures needed,
- level 2: Enhanced, general threat → increased security
- level 3: Terrorist threat → further increased measures.

7. Marine Pollution (MARPOL)

In 1973 IMO adopted the **International Convention for the Prevention of Pollution from Ships,** modified again in 1978. The **Marine Environment Protection Committee (MEPC)** performs the daily work and provides clarification. The actual regulations to prevent pollution by environmentally unfriendly substances are provided in "Annexes". Other regulations specified in Marpol, apply to platforms and other equipment at sea.

7.1 Annex I

This Annex deals with regulations in order to prevent the pollution of the seas by oil from ships. **Oil** is defined as petroleum in any form including crude oil, fuel oil, sludge, oil refuse and refined products. All such substances are listed in appendix 1 to this Annex.

There are two basic situations:
- Oil and oily mixtures generated in **Engine Rooms and machinery spaces** of a ship not being an oil tanker of 400 GT and above, and engine rooms of any oil tanker
- Oil and oily mixtures resulting from cargo pump rooms, cargo handling, cargo tank cleaning, etc. on **Oil Tankers**.

All **Engine Rooms and Machinery spaces** generate waste oil, sludge and oil-polluted bilge water. Waste oil and sludge will be collected in waste oil tanks and sludge tanks, and the bilge water via the bilge wells, in bilge water holding tanks. After settling, the water in the bilge water holding tank can be pumped into the sea, under the following conditions:
- the oil and oily-mixture is not mixed with cargo residues
- does not come from cargo pump rooms
- the vessel is not in a Special Area
- the vessel is underway at sea
- the oil content of the effluent without dilution does not exceed 15 parts per million (PPM), and the ship has filtering equipment in operation as required by regulation 16 of the Annex.

To be allowed to discharge oil and oily water from engine rooms while sailing in a Special Area, filtering equipment must be on board with an oil content meter and a device that automatically stops the discharge when the oil content exceeds 15 PPM.

The content of the bilge holding tank is pumped to an oil/water separator. This is a vertical settling tank, where the oil separates from the water, often followed by a filter which filters the remaining oil (if any) out. In the settling tank, a probe measures the presence of oil, and starts a pump, discharging the oil to the waste oil tank. If the probe does not find oil, the pump stops. The remaining water is pumped overboard via the oil-content meter which checks, via a full flow, or a bypass flow, the oil content in the processed bilge water.
If the oil content is more than 15 PPM, a pre-alarm is generated, but the discharge is still not stopped. If the oil content is consistently over 15 PPM, after ± 20 seconds a second alarm is generated. This second alarm stops the discharge.
The automatic stopping device can be a three-way valve, a combination of two alternating working valves or a pump stop. The automatic stopping device must be so arranged, that in case of a failure or in power-off condition, no discharge into the sea is possible.

All the equipment must be **Type Approved** and well maintained.

All operations, such as fuel bunkering, transfer of waste oils and sludge, handling of bilge water, defective filtering equipment and accidental discharges must be recorded in the **Oil Record Book** (Part I).

Special Areas, such as the North-West European Waters, the Baltic Sea and the Mediterranean can be found in regulation 10 of the Annex.

Oil Tankers generate cargo residues, remains from cargo line blowing, manifold-drip trays, tank washings, pump room bilge water, etc. These oily-residues are collected in the slop tank(s) of the vessel. It is, under no circumstances, allowed to transfer such oily-residues to the engine room.

Oil Tankers have, apart from engine-room generated oils, another problem. When an oil cargo is discharged, there is always residue, and often the tanks must be cleaned to prepare them for other cargo.

Washing is done with rotating water jets in the tanks, generating an oily water mixture, which is pumped to the so-called slop tank. There it is left to settle into oil and water.
Tank washing is performed using tank washing machines. These machines are water pressure driven, which rotating water jets, which reach every corner of the tank. While washing, the washing water is continuously pumped to another tank or the slop tank.

Water washing is carried out to enable tank entry. To achieve a gas-free condition, all the oil that can generate gas, needs to be removed. This is best done by washing the tank. After washing and pumping away the slops, the tank is to be properly re-inerted, after which the tank has to be ventilated untill the oxygen content is 21%. By following this procedure, there is never an explosive mixture.

After settling, the contents of the slop tank are pumped into the sea, under the following conditions:

- the tanker is not within a Restricted Area
- the tanker is more than 50 nautical miles from the nearest land
- the ship is underway at sea
- the instantaneous rate of discharge of oil content does not exceed 30 liters per nautical mile
- the total quantity of oil discharged into the sea does not exceed:
  - for existing tankers, 1/15,000 of the total of the particular cargo of which the residue formed a part,
  - for new tankers, 1/30,000 of the total quantity of the particular cargo of which the residue formed a part

Sewage treatment plant

- the tanker has in operation **Oil Discharge and Monitoring Equipment** and a slop tank arrangement as required by regulation 15 of this Annex.

The **Oil Discharge and Monitoring Equipment (ODME)** must be type approved. Oil tankers over 150 GT must be equipped with an ODME.

All operations must be recorded in the Oil Record Book (Part II).

The remaining oil is to be retained in the slop tank, either to be pumped ashore later or when suitable mixed with other cargo, usually only possible with crude (load-on-top-system). If this is not possible, the content of the slop tank has to be pumped ashore at a reception facility.

Crude tankers, during discharge, wash their tanks along with their cargo, to prevent the accumulation of sediment. The cargo oil is pumped through the rotating jets under high pressure and the sediments are kept mixed with the cargo and pumped ashore with the cargo. This is called **Crude Oil Washing (COW)**. The rotating jets are the same as used during tank washing.

A problem connected with high pressure water washing and COW is that static electricity is generated. Crude Oil Washing (and water washing) is therefore only allowed at an atmosphere with reduced oxygen (5%), below the level that explosions or fire can occur.
COW is compulsory under Marpol legislation (**Inert Gas** is a consequence). To achieve an atmosphere of less than 5% oxygen above the cargo or in the empty tank, the exhaust gas of the boiler, after washing, flows into the tank during discharge.

Restricted area
A restricted area is an area at sea where nothing may be pumped overboard. For example, the Mediterranean and Baltic are restricted areas.

All tankers need their cargo and ballast water in completely separate tanks. These are called **Segregated Ballast Tanks (SBT)**.
All handling of oils and ballast water has to be accurately administrated and entries are to be kept on board for three years.
The minimum SBT capacity of a tanker is regulated to ensure sufficient ballast capacity for safe navigation.

7.2 Annex II

This Annex of Marpol regulates the prevention of pollution by Noxious Liquid Substances, in general called 'Chemicals'. These ´Chemicals´ are categorized. Depending on the danger to the environment and the fire hazard properties, the regulations are more stringent.

A special booklet, issued by IMO, the so-called **International Bulk Chemical Code (IBC code)** gives a listing of requirements for ships that carry noxious liquid substances.
For chemical tankers with a keel laying date before 1 July 1986 the **BCH code** is applicable. **Noxious liquid substances** divided in four categories: A, B, C and D.
Category A is the most toxic, and category D, practically non-toxic. When discharged into the sea after tank cleaning or de-ballasting operations they would be a major hazard (cat. A) to a recognizable hazard (cat. D) to either marine resources or human health.
Depending on the cargo category, the ship's cargo tanks have to meet special requirements, with regard to location, distance from ship's side or bottom, i.e. double hull requirements. Therefore the ships are divided into Types I, II and III.

Incinerator

Pumping, piping and unloading arrangements are regulated. Slop handling and mandatory pre-wash (cleaning and discharge of the tank washings ashore after unloading) are prescribed.

Stability in intact and damaged condition is also an important issue.

Another important requirement for all chemical tankers is the total quantity of **residue on board** after discharge. Special cargo pumps, or built-in devices in the cargo pumps allow emptying of the tanks untill only a minor quantity (a few liters per tank) is left behind; this is called the minimum stripping quantity.
The last drops are pumped out via a small pipe, via the normal discharge line to the manifold.

As with all other tankers, all cargo handling has to be accurately recorded in the **Cargo Record Book**, without delay. The relevant equipment required for chemicals, and the required procedures, are described in a specific book, the *Procedures and Arrangements Manual*.

Each chemical tanker has to be provided with an **International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk**, with an attached list of cargoes that the ship is fit to carry, a tank plan, tank groups, and a list of additional requirements. On BCH code chemical tankers this certificate is called the **Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk**.
This certificate has a validity of five years and runs parallel to the ship's Special Survey cycle. Annual survey of the equipment is mandatory after which the certificate is endorsed.

WASTE MANAGEMENT

Getting rid of waste in the proper way is a huge problem. Nearly everything coming on board is packed, from meat to toilet paper, in cartons and wooden boxes, plastics, foil and hardware, glass, tin, other metals, etc. Passenger ships, especially, are huge waste generators.

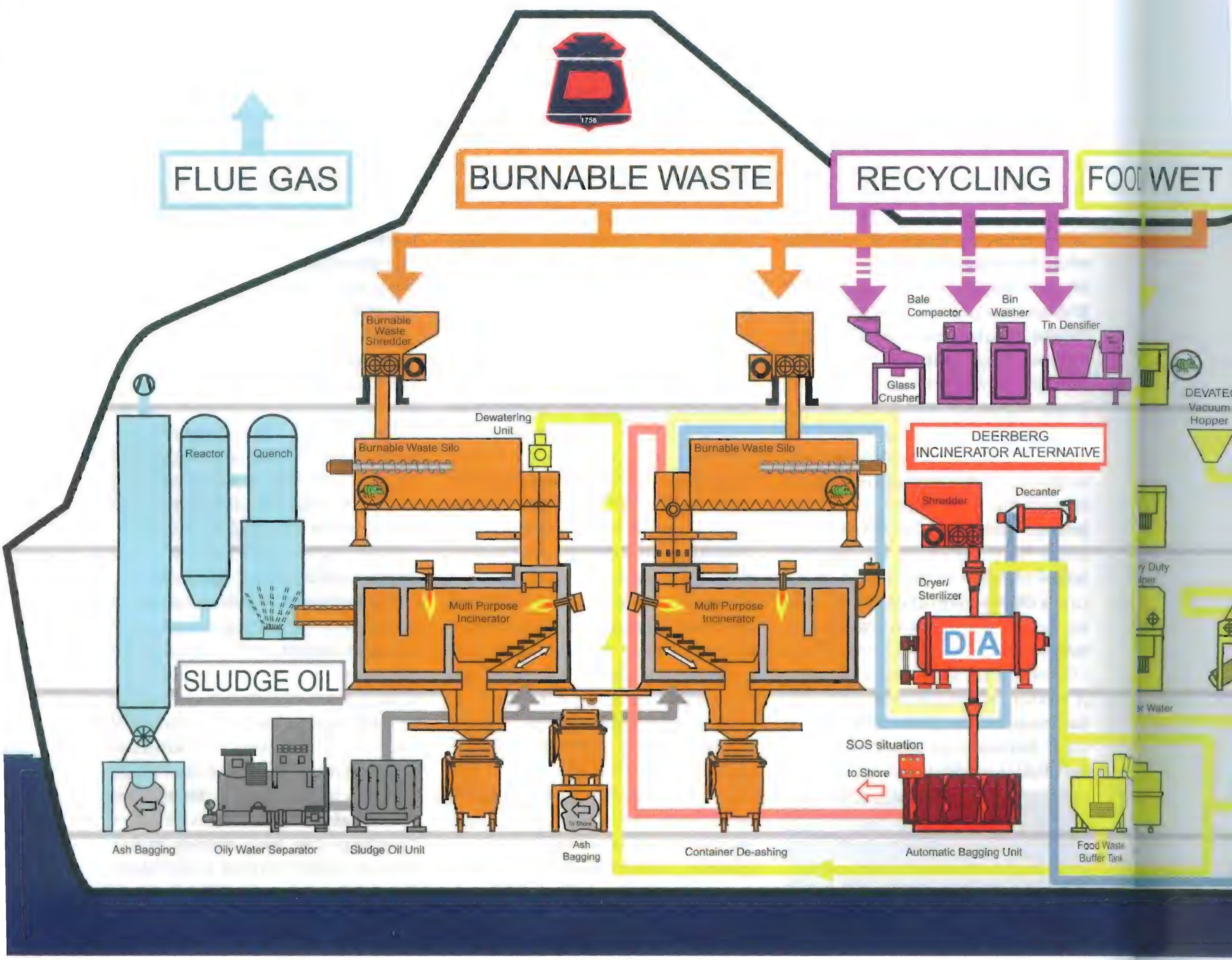
The remains of food can usually be dumped into the sea, but in not port. Port authorities where passenger ships call daily, strongly object to waste dumping and have stringent requirements to prevent it. Not only for passenger ships, but for all ships.

For cartons and paper the incinerator has been developed, although burning sludge is sometimes problematic. Sewage has to be dealt with, also. Numerous firms supply an efficient working treatment unit. Dry waste compactors are commonly installed.

Sewage can be divided into grey and black liquid. Grey is the washing water and water generated in the galleys. This can be stored in a tank and subject to regulations, is allowed to be pumped into the sea.

Black water from toilets must be treated biologically and chemically before it goes overboard. Passenger ships can not do this in port, so they have to store it and keep it on board untill they are (far) at sea.

Some ships have advanced waste



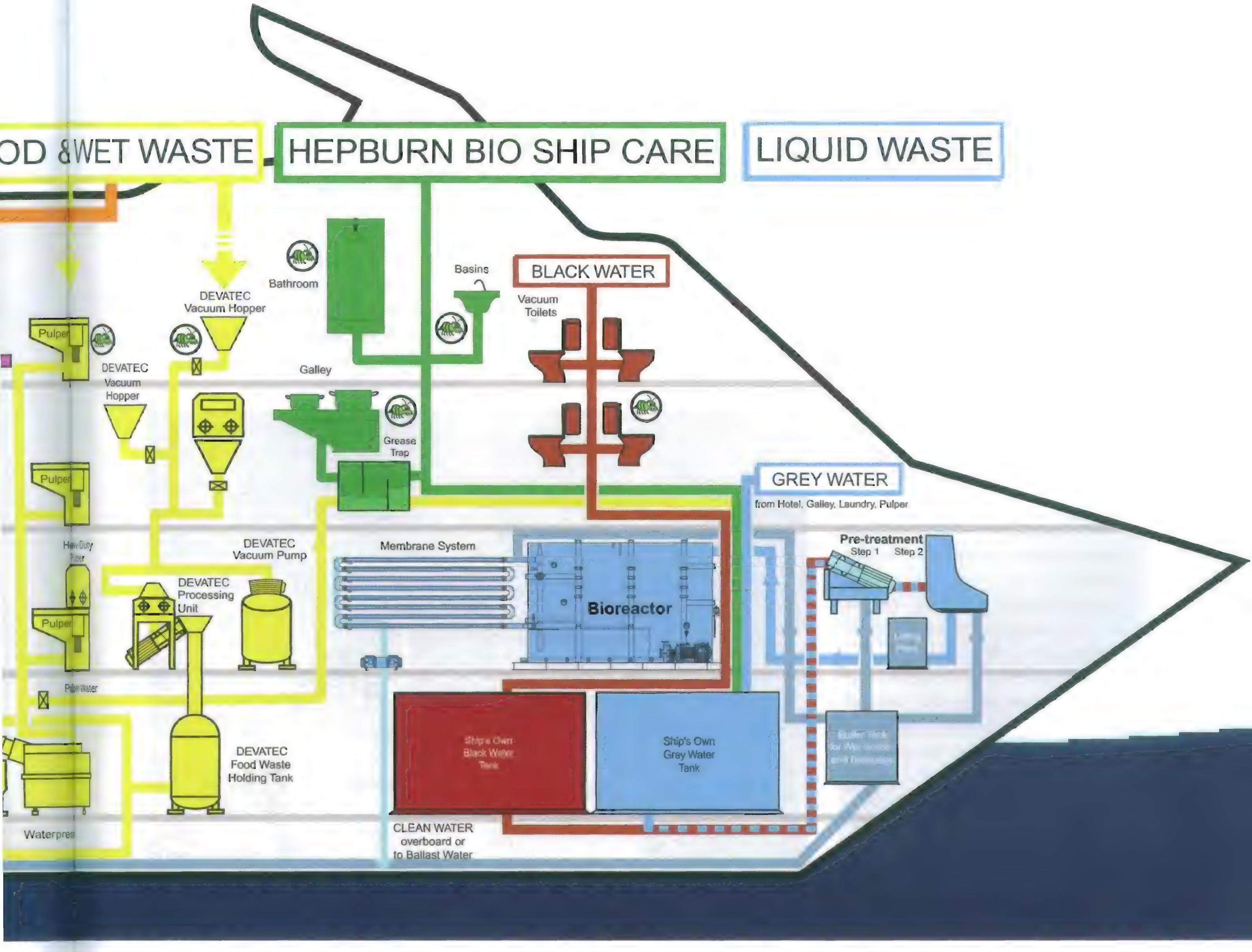
water treatment plants allowing sea discharge of end-products, as well as in port, etc. The plants are certified and audited by sampling.

Nowadays there are firms which supply the whole package, as shown in the picture. The various problems are solved in the following ways:

- Liquid waste, grey and black water, undergoes biological treatment before going overboard.
- Food and wet waste is collected and made free of water by condensing and drying. The water goes to the grey water system. The dry residue is bagged automatically and burned.
- Tin and glass is crushed, shredded, cleaned, dried and split, for collection and transport ashore, and as far as possible, burnt in an incinerator.
- Engine-room generated sludge is also dealt with in the incinerator.

In the end, ashes and flue gas remain. Ashes go ashore, compacted tin, plastics and glass at times.

Incinerators are complex furnaces. The initial heat in the furnace is generated by oil burners, the waste to be burnt, dropped from above on a traveling bed. The necessary heat is partly produced by the waste itself. The end product is ashes and flue gas. Flue gas disappears into the atmosphere and the ashes are cooled, bagged and transferred ashore.



NB: Marpol Annex II has been revised. All noxious liquid substances have been reviewed and re-categorized into X, Y and Z.
For example, edible oils were categorized as category D, a 'recognizable hazard', but because the cargo residues solidify, they are now judged to be a more serious hazard for the environment.

7.3 Annex III

This Annex regulates the carriage of **Packed Harmful** substan-ces. The carriage of harmful sub-stances is prohibited, except in accordance with the provisions of this Annex. Packages have to be labeled with the correct name and durable mark or as a marine pollutant.
The packing must be adequate. There are **stowage requirements** and quantity limitations. Throwing cargo overboard is only allowed if the ship or lives are at risk. This type of cargo has to be reported (type, quantity, location) to harbor authorities in each port.
The relevant certificate is called: **Document of Compliance for the Carriage of Dangerous Goods**.

7.4 Annex IV

This Annex regulates the **Prevention of Pollution by Sewage**, applicable to ships over 400 GT. Every ship must be equipped with a **sewage treatment system**, comminuting and disinfecting system or a holding tank.

Two criteria:
- When a ship has an approved treatment system sewage can be discharged
- Ships having a comminuting system can discharge sewage 3 miles beyond the nearest land.

The size of the **holding tank** depends on the ship's normal operating schedule, and there must be adequate connections for discharge into a reception facility. The content of the holding tank can be discharged overboard at least 12 miles from shore and only when moving at a speed of at least 4 knots.

7.5 Annex V

This Annex regulates the **Prevention of Pollution by Garbage**. Garbage means all kinds of victuals and domestic and operational waste, needing to be disposed of continuously or periodically, except substances defined under other Annexes.
Disposal into the sea of plastics into the sea is always prohibited. This includes ropes, fishing nets and plastic bags. Floating waste like dunnage, lining and packing material, is allowed to be disposed of at least 25 miles from the nearest land. Food waste, paper, rags, etc., at least 12 miles from shore. If the latter is ground into small particles, max. 25 mm, 3 miles is sufficient.

Ships operating in special areas have to comply with more strict discharge standards. On ships intended for long voyages, waste from packages, i.e. wood, carton, plastics, etc., can be disposed of in an incinerator. This is a simple stove, where the waste is put into the fire-space, and a simple gas-oil burner ignites the waste and if necessary, keeps it burning. The ashes may be disposed of in the sea.
A ship must have a **garbage management plan** and a record must be kept, similar to substances described under other Annexes.

Garbage

7.6 Annex VI

Annex VI deals with air pollution caused by ships. This Annex came into force the 19th of May 2005. It restricts the emission of:
- Substances which attack the ozone-layer,
- Nitrogen-Oxygen compounds NO(x)
  Sulphur-Oxygen compounds SO(x).
- Volatile Organic Compounds (VOC)
  Exhaust of incinerators.

NOx and SOx emissions are directly related to the quality of the fuels burnt in ship's diesels or boilers, which is a matter of economics. Fuels available are the leftovers of the refinery. The alternative, low-sulphur diesel oil is too expensive. However, in certain areas and ports, pollution is drastically restricted, and clean diesel oil has to be used to fulfill the requirements. Incinerators have to be provided with type-approval, which is related to the quality of the burning process. IMO is trying to standardize the requirements from the various governments.

Air pollution

When danger of oil pollution exists, harbor authorities require precautions to prevent spreading of the oil. Normally a 'flowboom' is laid around the ship.

8. Ballast Water Management (BWM)

Ships need ballast water for many reasons: to achieve sufficient draft and stability, to reduce stress, to correct list or trim, etc. Ships normally take ballast during or after discharging cargo, in the port of discharge. Mud and the local organisms come aboard with the ballast water. During the voyage to a port of loading, the mud settles and organisms may grow. In the port of loading, the ballast water, or a part of it, has to be pumped out. Most of the mud stays on board. The majority of the organisms, however, are discharged with the water at the port of loading and may harm the local environment. Due to the growing amount of ballast water transported over the world from port to port and region to region, a great environmental problem has been created. Species are brought to places where they become dominant to the existing species, resulting in environmental unbalance or even danger to the environment. Through IMO, a resolution has been adopted with regulations and guidelines to stop / minimise this transport of invasive species. The aim is to reduce the transport of invasive species drastically. This resolution is expected to come into force globally in phases, in 2009, depending on ballast capacity and the date of construction of the particular ship (see table). Some countries, however, implement the resolution at an earlier date.

The subject has been divided into a sediment problem and the problem of organisms. The amount of mud has to be minimized by taking ballast in deep water and by removing mud when it has settled. Getting rid of sediment is not easy. The best way is manually with a fire hose with low pressure and high volume, that hoses the mud towards the suction of the ballast pump and simultaneously pumps the water and mud overboard. This process is rather easy in large ballast tanks, but nearly impossible in low double bottom tanks and very impracticable during a voyage.

Apart from the environmental problem, the ship's loading capacity is reduced by the weight of the mud. This weight can vary from just a few tons in a small coastal vessel, up to 2000 tons in case of a capesize bulk carrier, or a large tanker. Therefore, the sediment content has to be monitored. The amount of sediment normally stabilizes, and is the main component of the 'ship's constant'. This is the difference between what the ship should be able to load and what it actually can load until the limits indicated by the freeboard requirements are reached.

Removal of sediment can be done in various ways. Disposal is allowed at sea at a minimum of 200 nm from shore and a minimum of 200 meter water depth. In port, or during repairs at a shipyard, disposal needs to be carried out at special reception facilities.

In order not to arrive in a loading port with the ballast water taken on board in the discharge port, the ballast has to be changed at sea during the voyage. Water taken in at 200 nm from shore and where the water depth is 200 meter or more, is considered 'clean'.

Changing the ballast water can be performed in three ways:

1. Sequential method, emptying and refilling each individual tank,
2. Flow-through method, replacing the water by adding to and simultaneously overflowing of the tank,
3. Dilution method, filling over the top while simultaneously pumping the water out.

The tank content is considered changed when 95 % of the water has been exchanged. When method 2 or 3 is chosen, changing is considered complete when three times the volume of the tank has been pumped through. The entire procedure involves:
free surface effects, draft, trim, propeller immersion, minimal draft forward to prevent slamming, visibility from the bridge, stability, stress, sloshing, possible over-pressurizing, prevention of internal transfer of ballast water, etc.
Planning is necessary to change ballast and once started, has to be completed; otherwise the organisms may grow again.

An approved Ballast Water Management Plan has to be on board every ship, explaining how to change ballast, taking the above into account.
A designated person in charge of ballast water management who is responsible for the training of other personnel has to be appointed.
The form of the plan and the record of BWM activities is stated in the IMO resolution. A Ballast Water Record Book also has to be kept.

Sediment is the collection of very fine particles of all kinds of solids, dispersed in river and coastal water. Most is soil, but all kinds of particles can be part of it.
When water is pumped into a ship as ballast and comes to rest, the mud in the water settles down because of gravity, thus forming a layer of sediment on all horizontal surfaces. In uncoated tanks, rust from the tank construction will also be part of the sediment.
The quantity of sediment depends on the ship's size and the location where ballast is taken.

Table 1 summarizes the implementation schedule of the type of treatment required according to the age of ship and its ballast capacity as per the provisions of the Convention [regulation B-3].

Table 1 - Ballast water Implementation Schedule

<table>
<tr><th colspan="2">Ballast Capacity (m3)</th><th colspan="2">< 1500 m3</th><th colspan="2">≥ 1500 m3 but ≤ 5000 m3</th><th colspan="2">> 5000 m3</th></tr>
<tr><th colspan="2">Construction Date [keel laying]</th><th>< 2009</th><th>≥ 2009</th><th>< 2009</th><th>≥ 2009</th><th>< 2012</th><th>≥ 2012</th></tr>
<tr><td rowspan="11">First Intermediate or Renewal Survey, which ever occurs first after anniversary date of delivery in the year:</td><td>2009</td><td rowspan="8">D1 or D2</td><td rowspan="11">D2</td><td rowspan="6">D1 or D2</td><td rowspan="11">D2</td><td rowspan="8">D1 or D2</td><td rowspan="3"></td></tr>
<tr><td>2010</td></tr>
<tr><td>2011</td></tr>
<tr><td>2012</td><td rowspan="8">D2</td></tr>
<tr><td>2013</td></tr>
<tr><td>2014</td></tr>
<tr><td>2015</td><td rowspan="5">D2</td></tr>
<tr><td>2016</td></tr>
<tr><td>2017</td><td rowspan="3">D2</td><td rowspan="3">D2</td></tr>
<tr><td>2018</td></tr>
<tr><td>2019</td></tr>
</table>

Ballast Water Exchange Standard, D1

- 95% volumetic exchange
- or pumps through tree times the volume of each tank.

Ballast Water Treatment Standard, D2

- Approved treatment systems are to treat ballast water.

Electrolic cells for chlorination. (test installation)

While large gas tankers have fully automatic computer programs to run the pumping sequence, small ships may have to do this manually. Precautions have to be taken to prevent contamination of water when pumping is changed from one tank to another.
The quantity of organisms and mud can be reduced by not taking ballast during the night, when the organisms tend to come to the surface, in shallow water where propellers stir up the sediment or where dredging is in progress or has recently been done.

Filling an empty ballast tank with 'clean' water straightaway is the ideal solution to avoid sediment and organism problems. Heat treatment of water during filling, chlorination or the use of ultra-violet light are considered solutions, but these methods only kill the organisms solving only part of the problem. Prevention of the intake of mud, and the killing of organisms is possible using a centrifugal separator to separate the sediment from the water. The sediment goes back into the sea and the clean water goes into the ballast tank. Most organisms do not survive the centrifugal forces.
The remaining organisms still have to be killed by chlorination, but only with a fraction of the toxic chlorine (obtained by electrolysis of seawater) that would have to be used without separation. This system is type-approved by end first quarter 2008.

Facilities for ballast exchange and monitoring should be provided on new ships. These facilities could encompass tank entrance hatches with sampling opportunities, remote measuring of content, additional filling pipes, etc. The construction of tanks should minimize sedimentation by sloping horizontal areas like frames, flanges and girders. Another way to get rid of the sediment is to disperse the mud into the water during de-ballasting. Certain countries with long freshwater rivers, require the ballast exchange to be carried out twice: once before entering coastal waters, and again before going up river.

Centrifugal mud disposal unit Sedimentor (100 m3/hr) 1P = 2weight: ca. 200 kg

9. Documents

Some compulsory documents are shown on the following pages.

INTERNATIONAL TONNAGE CERTIFICATE (1969)

ISSUED UNDER THE PROVISIONS OF THE
INTERNATIONAL CONVENTION ON TONNAGE MEASUREMENT
OF SHIPS, 1969
UNDER THE AUTHORITY OF THE GOVERNMENT OF THE

REPUBLIC OF PORTUGAL
REGISTO INTERNACIONAL DE NAVIOS DA MADEIRA

for which the Convention came into force on **1st September 1987**

by

Germanischer Lloyd

Name of Ship	Official Number or Distinctive Number or Letters	Port of Registry	Date *)
SIDERFLY	CQUT IMO No.: 8412405	Madeira	27.08.1984

*) Date on which the keel was laid or the ship was at a similar stage of construction [Article 2(6)], ~~or date on which the ship underwent alterations or modifications of a major character [Article 3 (2)(b)], as appropriate.~~

MAIN DIMENSIONS

Length [Article 2 (8)]	Breadth [Regulation 2 (3)]	Moulded Depth amidships to Upper Deck [(Regulation 2 (2)]
95.09 m	14.60 m	6.95 m

The Tonnages of the ship are:

GROSS TONNAGE 2881

NET TONNAGE 1371

This is to certify that the tonnages of this ship have been determined in accordance with the provisions of the International Convention on Tonnage Measurement of Ships, 1969.

Issued at **Hamburg** on **22nd April, 2002**

GERMANISCHER LLOYD 1867

Germanischer Lloyd

i.V. Franzel – i.A. Wer

Franzelius Werner

The undersigned declares that he is duly authorized by the said Government to issue this certificate.

BUREAU VERITAS

INTERNATIONAL REGISTER FOR CLASSIFICATION OF SHIPS,
ESTABLISHED 1828.
REGISTRO INTERNACIONAL DE CLASIFICACION DE BUQUES,
FUNDADO EN 1828.

CERTIFICATE OF CLASSIFICATION
CERTIFICADO DE CLASIFICACION
No RTD0/AST0/2002011105111

NAME OF SHIP : VERISTAR
Nombre del Buque
Register No : 85L011
N° de Registro
Owners : MEMBERS
Armado
Flag : PANAMA
Bandera
Port of Registry : PANAMA
Puerto de matrícula
This is to certify that the above named ship has been entered in the Register Book with the classification symbols and notations :
El abajo firmante certifica que este buque ha sido inscrito en el Libro Registro con los símbolos de clasificación y menciones

I ✠ HULL; ✠ MACH; ✠ AUT-UMS; ✠ SYS-NEQ-1;
Hopper dredger
Unrestricted navigation
Dredging within 15 Miles from shore or within 20 miles from port

This certificate, issued within the scope of Bureau Veritas Marine Division General Conditions, is valid until :
Este certificado, expedido de acuerdo con las Condiciones Generales de la División Naval de Bureau Veritas es válido hasta el

8 January 2006

At/*Expedido en* Rotterdam, on/*el* 21 April 2002

By Order of the Secretary
Por Orden del Secretario
K. Docter

This certificate is invalid without the annexes listed. Conditions of use are given on page 2/2. *Este certificado no es válido sin los anexos indicadosen la página 2/2. Las condiciones para la utilización se detallan en la página 2/2.*

Any person not a party to the contract pursuant to which this certificate is delivered may not assert a claim against Bureau Veritas for any liability arising out of errors or omissions which may be contained in said certificate, or for errors of judgement, fault or negligence committed by personnel of the Society or its Agents in the establishment or issuance of this certificate, and in connection with any activities which it may provide.

Lloyd's Register

Certificate no:
ROT 0000001

Cargo Ship Safety Construction Certificate

Issued under the provisions of the International Convention for the Safety of Life at Sea, 1974, as modified by the Protocol of 1988 relating thereto,

under the authority of the Government of the Republic of Malta

by Lloyd's Register of Shipping

	Particulars of Ship
Name of ship	"MINERVA ASTRA"
Distinctive number or letters	9 H D W 7
Port of registry	Valletta
Gross tonnage	59,693
Deadweight of ship (metric tons)[1]	105946
IMO number	9230098
Type of ship*	~~Bulk carrier~~ Oil tanker ~~Chemical tanker Gas carrier Cargo ship other than any of the above~~
Date on which keel was laid[2]	01/2001

This is to certify:

1. that the ship has been surveyed in accordance with the requirements of regulation I/10 of the Convention;
2. that the survey showed that the condition of the structure, machinery and equipment as defined in the above regulation was satisfactory and the ship complied with the relevant requirements of chapters II-1 and II-2 of the Convention (other than those relating to fire safety systems and appliances and fire control plans) ;
3. that the last two inspections of the outside of the ship's bottom took place on - and -;
4. that an Exemption Certificate has been issued.

This certificate is valid until[3] 04 December 2006 subject to the annual and intermediate surveys and inspections of the outside of the ship's bottom in accordance with regulation I/10 of the Convention.

Completion date of the survey on which this certificate is based 05 December 2001

Issued at Rotterdam on 05 December 2001

LLOYD'S REGISTER OF SHIPPING ROTTERDAM

C.B.A. van Egmond
Surveyor to Lloyd's Register of Shipping

[1] For oil tankers, chemical tankers and gas carriers only
* Delete as appropriate
[2] Date on which keel was laid or ship was at a similar stage of construction or, where applicable, date on which work for a conversion or an alteration or modification of a major character was commenced.
[3] Insert the date of expiry as specified by the Administration in accordance with regulation I/14(a) of the Convention. The day and the month of this date correspond to the anniversary date as defined in regulation I/2(n) of the Convention, unless amended in accordance with regulation I/14(h).
Form 2221 (2002.09)

Certificate No. 101635/108/02/00

INTERNATIONAL LOAD LINE CERTIFICATE

Issued under the provisions of the
INTERNATIONAL CONVENTION ON LOAD LINES, 1966,
as modified by the Protocol of 1988 relating thereto
under the authority of the Government of

ANTIGUA AND BARBUDA

by GERMANISCHER LLOYD

Name of Ship	Distinctive Number or Letters	Port of Registry	Length (L) as defined in article 2 (8) (in metres)	IMO Number
MAERSK DUBLIN	*V2PW3*	*St.John's*	*277.490*	*9105918*

Freeboard assigned as:* { *A new ship*
{ ~~*An existing ship*~~

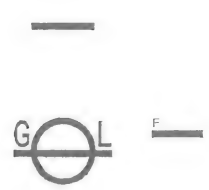
Type of ship:* { ~~*Type "A"*~~
{ ~~*Type "B"*~~
{ ~~*Type "B" with reduced freeboard*~~
{ *Type "B" with increased freeboard*

	Freeboard from deck line	Load Line
Tropical	*3885* mm (T)	--- mm above (S)
Summer	*3885* mm (S)	Upper edge of line through centre of ring
Winter	*3885* mm (W)	--- mm below (S)
Winter North Atlantic	--- mm (WNA)	--- mm below (S)

Note: Freeboards and load lines which are not applicable need not be entered on the Certificate.

Allowance for fresh water for all freeboards other than timber *260* mm.

The upper edge of the deck line from which these freeboards are measured is *0* mm *above/below the top of the freeboard (2nd) deck at side.*



THIS IS TO CERTIFY:

1. That the ship has been surveyed in accordance with the requirements of article 14 of the Convention.
2. That the survey showed that the freeboards have been assigned and load lines shown above have been marked in accordance with the Convention.

This Certificate is valid until *30th June, 2005* subject to annual surveys in accordance with article 14(1) (c) of the Convention.

Issued at *Hamburg* the *18th* day of *April, 2002*

Germanischer Lloyd

i.V. Franzelius   i.A. Bremer

Notes:
1. When a ship departs from a port situated on a river or inland waters, deeper loading shall be permitted corresponding to the weight of fuel and all other materials required for consumption between the point of departure and the sea.
2. When a ship is in fresh water of unit density the appropriate load line may be submerged by the amount of the fresh water allowance shown above. Where the density is other than unity, an allowance shall be made proportional to the difference between 1.025 and the actual density.

*Delete as appropriate

Form No. S750 / 2002-01 Page 1 of 4

Lloyd's Register

Certificate no:
ROT 0000001

Cargo Ship Safety Radio Certificate

This certificate shall be supplemented by a Record of Equipment of Radio Facilities (Form R) No: 9230098/01

Issued under the provisions of the International Convention for the Safety of Life at Sea, 1974, as modified by the Protocol of 1988 relating thereto,

under the authority of the Government of the Republic of Malta

by Lloyd's Register of Shipping

	Particulars of Ship
Name of ship	"MINERVA ASTRA"
Distinctive number or letters	9 H D W 7
Port of registry	Valletta
Gross tonnage	59,693
Sea areas in which ship is certified to operate (regulation IV/2)	A1 + A2 + A3
IMO number	9230098
Date on which keel was laid[1]	01/2001

This is to certify:

1. that the ship has been surveyed in accordance with the requirements of regulation I/9 of the Convention;
2. that the survey showed that:
   - 2.1 the ship complied with the requirements of the Convention as regards radio installations;
   - 2.2 the functioning of the radio installations used in life-saving appliances compiled with the requirements of the Convention;
3. that an Exemption Certificate has not been issued.

This certificate is valid until[2] 04 December 2006 subject to the periodical surveys in accordance with regulation I/9 of the Convention.

Completion date of the survey on which this certificate is based 05 December 2001

Issued at Rotterdam on 05 December 2001

LLOYD'S REGISTER OF SHIPPING ROTTERDAM

C.B.A. van Egmond
Surveyor to Lloyd's Register of Shipping

[1] Date on which keel was laid or ship was at a similar stage of construction or, where applicable, date on which work for a conversion or an alteration or modification of a major character was commenced.
* Delete as appropriate
[2] Insert the date of expiry as specified by the Administration in accordance with regulation I/14(a) of the Convention. The day and month of this date correspond to the anniversary date as defined in regulation I/2(n) of the Convention, unless amended in accordance with regulation 1/14(h).
Form 2206 (2002.09)

INTERNATIONAL OIL POLLUTION PREVENTION CERTIFICATE

(Note : This Certificate shall be supplemented by a Record of Construction and Equipment)

Certificate No. 2HO-0200M

Issued under the provisions of the
INTERNATIONAL CONVENTION FOR THE PREVENTION OF POLLUTION FROM SHIPS, 1973,
as modified by the Protocol of 1978 relating thereto (hereinafter referred to as "the Convention")
under the authority of the Government of
the Republic of Panama
by Nippon Kaiji Kyokai

Name of Ship	Distinctive Number or Letters	Port of Registry	Gross Tonnage
REEFER	.... IMO 1234567	Panama	7367

Type of ship:

~~Oil tanker~~*
~~Ship other than an oil tanker with cargo tanks coming under Regulation 2(2) of Annex I of the Convention~~*
Ship other than any of the above*

THIS IS TO CERTIFY:

1 That the ship has been surveyed in accordance with Regulation 4 of Annex I of the Convention; and

2 That the survey shows that the structure, equipment, systems, fittings, arrangement and material of the ship and the condition thereof are in all respects satisfactory and that the ship complies with the applicable requirements of Annex I of the Convention.

This Certificate is valid until 12 October 2004
subject to surveys in accordance with Regulation 4 of Annex I of the Convention.

Issued at Tokyo on 15 February 2002

Valid only when the Supplement No. S-2HO-0197M is available for inspection.

The undersigned declares that he is duly authorized by the said Government to issue this certificate.

NIPPON KAIJI KYOKAI Founded 1899 ClassNK

M. Otsuka

Managing Director
NIPPON KAIJI KYOKAI

See note(s) on the reverse.
Date of Initial Survey: 13 October 1999

*Delete as appropriate

IOPP(PNM)

1998

CARGO SHIP SAFETY EQUIPMENT CERTIFICATE

This Certificate shall be supplemented by a Record of Equipment (Form E)

(Form E No. R-9KK-0014SE)

Certificate No. 2NY-0101SE

Issued under the provisions of the

INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA, 1974

as modified by the Protocol of 1978 relating thereto under the authority of the Government of

the Republic of Panama

by NIPPON KAIJI KYOKAI

PARTICULARS OF SHIP

Name of Ship	REEFER
Distinctive Number or Letters	......
Port of Registry	PANAMA
Gross Tonnage	7367
Deadweight of Ship (metric tons) *1	---
Length of Ship(Regulation III/3.10)	127.38 m
IMO Number	IMO 1234567
Type of Ship: *2	~~Bulk carrier~~ / ~~Oil tanker~~ / ~~Chemical tanker~~ / ~~Gas carrier~~ / Cargo ship other than any of the above
Date on which keel was laid: *3	29 June 1998

THIS IS TO CERTIFY:

1 That the ship has been surveyed in accordance with the requirements of Regulation I/8 of the Convention, as modified by the 1978 Protocol.

2 That the survey showed that:

2.1 the ship complied with the requirements of the Convention as regards fire safety systems and appliances and fire control plans;

2.2 the life-saving appliances and the equipment of the lifeboats, liferafts and rescue boats were provided in accordance with the requirements of the Convention;

2.3 the ship was provided with a line-throwing appliance and radio installations used in life-saving appliances in accordance with the requirements of the Convention;

2.4 the ship complied with the requirements of the Convention as regards shipborne navigational equipment, means of embarkation for pilots and nautical publications;

2.5 the ship was provided with lights, shapes, means of making sound signals and distress signals, in accordance with the requirements of the Convention and the International Regulations for Preventing Collisions at Sea in force;

2.6 in all other respects the ship complied with the relevant requirements of the Convention.

3 That the ship operates in accordance with Regulation III/26.1.1.1 within the limits of the trade area

---

4 That in implementing Regulation I/6 (b) the Government has instituted Mandatory Annual Surveys.

5 That an Exemption Certificate has / ~~has not~~ *2 been issued

This certificate is valid until 8 October 2003.

Issued at New York on 28 May 2002.

(N. Tagashira)

For and on behalf of Managing Director

NIPPON KAIJI KYOKAI

Date of Renewal Survey : 9 October 2001

*1 For oil tankers, chemical tankers and gas carriers only.

*2 Delete as appropriate.

*3 Date on which keel was laid or ship was at a similar stage of construction or, where applicable, date on which work for a conversion or an alteration or modification of a major character was commenced.

SE(PNM)-74/78P 2002.1

Certificate of Class

8716100
IMO-No.

032348
GL-Register-No.

This is to certify that the Ship

" POLARIS "

Flag	**Federal Republic of Germany**	Call Sign	**DGPF**
Port of Registry	**Hamburg**		
Owner	**Reederei Heinz Corleis GmbH & Co. KG MS 'POLARIS'**		
Shipyard	**J.J. Sietas KG Schiffswerft GmbH & Co.**		
Place of Build	**Hamburg**		
	Launching **1988-07-04**	Completion	**1988-10-01**

has been surveyed at **Bilbao**
on **2003-10-25** by our Surveyor(s) in accordance with this Society's Rules.

Character of Class:

Hull ✠ **100 A5 E4 with freeboard 1.165 m**
G SOLAS-II-2,Reg.19
Ro-Ro-Ship, Strengthened for Heavy Cargo, Equipped for Carriage of Containers

Machinery ✠ **MC E4 AUT**

Period of Class running from **1st November 2003**
This Certificate is valid until **31st October 2008**

provided that prescribed surveys are effected by their due dates.

Germanischer Lloyd

Hamburg, 10th January 2005

(Arndt) **(Fichelmann)**

Germanischer Lloyd

This Certificate of Class is valid only in connection with the Technical File and all endorsements made by Surveyors to Germanischer Lloyd on Survey Statements in respect of this vessel. The latest edition of the General Terms and Conditions of Germanischer Lloyd is applicable (see Chap. I-Ship Technology, Part 0-Classification and Surveys). Germanischer Lloyd Aktiengesellschaft; Registered Office Hamburg , HR B 31393

Page 1/2

DET NORSKE VERITAS

SAFETY MANAGEMENT CERTIFICATE

DNV Ship Id. No.:
00000
DNV Company No.:
000000
Certificate number:
D00000/021202F

Issued under the provisions of the INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA, 1974, as amended

Issued under the authority of the Government of:

Norway

by Det Norske Veritas

Name of ship:	**"FELICIA"**
Distinctive number or letters:	**XXXX1**
Port of Registry:	**KRAGERØ**
Type of Ship*:	**Other Cargo Ship**
Gross Tonnage:	**11658**
IMO Number:	**00000000**
Name and address of the Company: (as per ISM Code sec. 1.1.2)	**Benkestok Shipping** **Rørvikveien 32** **3770 Kragerø** **Norway**

THIS IS TO CERTIFY THAT the safety management system of the ship has been audited and that it complies with the requirements of the International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code). following verification that the Document of Compliance for the Company is applicable to this type of ship.

The Safety Management Certificate is valid until **2007-10-14** ,subject to periodical verification and the validity of the Document of Compliance remaining valid.

Issued at: **Det Norske Veritas, Høvik, Norway**
Date of Issue: **2002-12-02**

DET NORSKE VERITAS * 1864 *

Sign.

Name
Head of Section

* Insert the standard IMO ship type.

CERTIFICATE No: SPECIMEN

INTERNATIONAL SHIP SECURITY CERTIFICATE

Issued under the provisions of the

INTERNATIONAL CODE FOR THE SECURITY OF SHIPS AND OF PORT FACILITIES (ISPS CODE)

under the authority of the Government of

FLAG STATE

(name of state)

by the **AMERICAN BUREAU OF SHIPPING**

Name of Ship:	VESSEL
Distinctive Number or Letters:	ABCD
Port of Registry:	PORT
Type of Ship[1]:	Bulk Carrier
Gross Tonnage:	45,000
IMO Number:	1234567
Name and Address of Company:	COMPANY NAME
	STREET
	POST CODE, CITY
	COUNTRY
	(see paragraph 1.1.2 of the ISM Code)

THIS IS TO CERTIFY THAT:

1. the security system and any associated security equipment of the ship have been verified in accordance with section 19.1 of part A of the ISPS Code;

2. the verification showed that the security system and any associated security equipment of the ship is in all respects satisfactory and that the ship complies with the applicable requirements of chapter XI-2 of the Convention and part A of the ISPS Code;

3. the ship is provided with an approved Ship Security Plan.

This Certificate is valid until EXPIRY DATE, subject to verification in accordance with section 19.1.1 of part A of the ISPS Code.

Date of the initial/renewal verification on which this certificate is based: INITIAL DATE
(dd/mm/yyyy)

ABS

Issued at: PORT
(place of issue of the certificate)

Date of Issue: DATE

AMERICAN BUREAU OF SHIPPING ABS ROTTERDAM

(Signature of the duly authorized official issuing the certificate)

[1] Insert the type of ship from among the following: Passenger Ship; Passenger High Speed Craft; Cargo High Speed Craft; Bulk Carrier; Oil Tanker; Chemical Tanker; Gas Carrier; Mobile Offshore Drilling Unit; Other Cargo Ship

ISSC Revision 2 Page 1 of 1

Germanischer Lloyd

SUEZ CANAL
SPECIAL TONNAGE CERTIFICATE

Name of Ship	Official Number	Signal letters	Port of Registry	Tonnage on International Tonnage Certificate: Gross	Tonnage on International Tonnage Certificate: Net	IMO-No.
AIDAvita	905689	VSTN3	London	42289	20877	9221554

DETAILS OF TONNAGE FOR THE ABOVE-NAMED SHIP WHEN PASSING THROUGH THE SUEZ CANAL

The space measured for Gross Tonnage in this Ship comprises the following and no others, viz:

	Cubic Metres	Tons of 100 Cubic Feet
1. Space under the tonnage deck including part of double bottom available for oil drain tank	68 391.20	24 142.09
2. Space or spaces between the tonnage deck and the uppermost deck: Lower tween deck		
Upper tween deck		

3. Closed-in spaces under or in permanent constructions above the uppermost deck, viz.:

	Cubic Metres
Space between uppermost deck and shelterdeck with side openings	
Forecastle	
Bridge space 12 001.65 + 13 172.47; 12 870.63 + 7 882.57	45 927.32
Poop	
Break or breaks	
Turret cbm Trunk cbm	

							Cubic Metres
Roundhouses (1st Tier)	10 588.72 cbm	cbm	cbm	cbm	cbm	cbm	13 714.54
(2nd Tier)	cbm	cbm	cbm	cbm	cbm	cbm	
(3rd Tier)	cbm	cbm	cbm	cbm	cbm	cbm	
(Upper Tiers)	1 426.15 cbm	1 533.36 cbm	141.61 cbm	24.70 cbm	cbm	cbm	
cbm	cbm	cbm	cbm	cbm	cbm	cbm	
Side screens cbm	101.30 cbm	98.31 cbm	56.92 cbm	34.16 cbm	cbm	cbm	290.69
Hatchways cbm	cbm	cbm	cbm	cbm	cbm	cbm	
cbm	cbm	cbm	cbm	cbm	cbm	cbm	

Total cbm One-half percent of the gross tonnage cbm Excess

	Cubic Metres	Tons of 100 Cubic Feet
Total of Tonnage of closed-in spaces above the uppermost deck	59 932.55	21 156.19
GROSS REGISTER TONNAGE	128 323.75	45 298.28
DEDUCTIONS FROM GROSS TONNAGE (Details on page 2)	7 527.48	2 657.20
NET TONNAGE IF A SAILING SHIP	120 796.27	42 641.08

NOTE: for particulars of spaces not included in the Measurement for Gross Tonnage, see page 3

FURTHER DEDUCTIONS FOR PROPELLING POWER IN THE CASE OF /S (Details on page 4)

Either (1) applicable to ships with fixed bunkers:

	Cubic Metres
(a) Engine room as measured	
(b) Permanent bunkers as measured	
Total deduction for propelling power	

NET REGISTER TONNAGE OF /S BY ACTUAL MEASUREMENT

Or (2) Danube Rule:

	Cubic Metres		
(a) Engine room as measured	5 331.90		
(b) In a Screw Motor /S + 75 percent of engine room as measured	3 998.93		
(c) In a Paddle /S + 50 percent of engine room as measured			
Total deduction for propelling power		9 330.83	3 293.78
NET REGISTER TONNAGE OF Motor /S BY DANUBE RULE		111 465.44	39 347.30

THIS IS TO CERTIFY that the British ship above-named has been re-measured, and that the Tonnage ascertained as above is in accordance with the rules adopted by the International Tonnage Commission at Constantinople.

Given under my hand at Hamburg the 22nd day of April, 2002

Germanischer Lloyd

Franzelius Werner

Survey Intervals and Validity of Certificates

Certificate or Document	Reference	Restrictions
1. SOLAS 74		
Passenger Ship Safety Certificate	Reg. I / 12	Vessels carrying more than 12 Passengers
Cargo Ship Safety Construction Certificate	Reg. I / 12	Cargo Vessels > 500 GT
Cargo Ship Safety Equipment Certificate	Reg. I / 12	Cargo Vessels > 500 GT
Cargo Ship Safety Radio Certificate	Reg. I / 12	Cargo Vessels > 300 GT
Cargo Ship Safety Certificate 1	Protocol 88 Reg. I / 12	Cargo Vessels > 500 GT
International Ship Security Certificate (1. July 2004)	Reg. XI-2/1.12 ISPS Code A/19.2	Passenger Ships, MODU's Cargo Vessels > 500 GT
Safety Management Certificate (ISM)	Reg. IX / 4 ISM Code Reg. 13.4	Passenger Vessels Cargo Vessels > 500 GT MODUS > 500 GT
Document of Compliance (ISM)	Reg. IX / 4 ISM Code Reg. 13.2	Companies operating Companies operating Vessels > 500 GT
High Speed Craft Safety Certificate	Reg. X / 3 HSC Code 1.8	High-Speed Craft
International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk	Reg. VII / 8 IBC Code Sec. 1.5	Vessels carrying Dangerous Chemicals in Bulk, built on or after 1 July 1986
International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk	Reg. VII / 11 IGC Code Sec. 1.5	Vessels carrying Liquefied Gases in Bulk, built on or after 1 July 1986
Document of Compliance with the special Requirements for Ships carrying Dangerous Goods	Reg. II – 2 / 19.4 (former 54.3) HSC Code 7.1.2.5.	Vessels carrying Dangerous Goods
Minimum Safe Manning Certificate	Reg. V / 14.2 (former 13 (b))	Cargo Vessels > 500 GT Passenger Vessels
Document of Authorization for the Carriage of Grain	Reg. VI / 9	Vessels carrying Grain in Bulk
International Certificate of Fitness for the Carriage of INF Cargo	Reg. VII / 16 INF Code Reg. 1.3.4	Vessels carrying Packaged Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes
2. MARPOL 73 / 78 Annex I		
International Oil Pollution Prevention Certificate (IOPP Certificate)	Reg. 5	Oil Tankers > 150 GT Other Vessels > 400 GT
3. MARPOL 73 / 78 Annex II		
International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk	Reg. 12 A	Chemical Tankers
International Pollution Prevention Certificate for the Carriage of Noxious Liquid Substances in Bulk (NLS Certificate)	Reg. 11	Other Vessels carrying Noxious Liquid Substances in Bulk
4. MARPOL 73 / 78 Annex IV		
International Sewage Pollution Prevention Certificate	Reg. 4	Vessels > 400 GT and/or carrying more than 15 Persons
6. MARPOL 73 / 78 Annex VI (Entry into Force 19 May 2005)		
International Air Pollution Prevention Certificate	Reg. 6	Vessels > 400 GT Platforms and Drilling Rigs
Engine International Air Pollution Prevention Certificate	NO_X Technical Code Reg. 2.2.9	Marine Diesel Engines > 130 Kw
7. Load Line 1966		
International Load Line Certificate	Art. 16, ILLC Protocol 88 Art. 18	Vessels > 24 meter in Length
8. International Tonnage Convention 69		
International Tonnage Certificate	Art. 7	Vessel > 24 meter in Length

	Flag State has accepted HSSC																			
	1				2				3				4				5			
Duration	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60
1 year				R				R				R				R				R
5 years				A				A or IM				A or IM				A				R
5 years				A				A or P				A or P				A				R
5 years				P				P				P				P				R
5 years	see individual certificates (HSSC)																			
5 years									IM											R
5 years									IM											R
5 years				A				A				A				A				R
5 years				A				A				A				A				R
5 years				A				A or IM				A or IM				A				R
5 years				A				A or IM				A or IM				A				R
5 years																				R
unlimited, if no modifications	No surveys. Document issued following examination of the appropriate documentation																			
unlimited, if no modifications	No surveys. Document issued following examination of the appropriate documentation																			
5 years				A				A				A				A				
5 years				A				A or IM				A or IM				A				R
see SOLAS																				
5 years				A				A or IM				A or IM				A				R
5 years									IM											R
5 years				A				A or IM				A or IM				A				R
Pre-certification	**Pre-certification Survey of Marine Diesel Engines** – Concerning Regulation 13 and NOx Technical Code, a pre-certification survey shall be performed which shall be such as to ensure that the engine, as designed and equipped, complies with the NOx emission limits. If this survey confirms compliance, the Administration shall issue an: Engine International Air Pollution Prevention (EIAPP) certificate. **The pre-certification survey shall generally be done at the engine manufacturer's facilities.**																			
5 years				A				A				A				A				R
unlimited, if no modifications	No surveys. Document issued following examination of the appropriate documentation																			

Surveys

An **Initial Survey** – is a complete inspection before a ship is put into service of all the items relating to a particular certificicate to ensure that the relevant requirements are complied with and that these items are satisfactory for the service for which the ship is intended.

A – Annual Survey: An annual survey is a general inspection of specified items relevant to the particular certificate to ensure that they have been maintained and remain satisfactory for the service for which the ship is intended.

I – Intermediate Survey: An intermediate survey is an inspection of specified items relevant to the particular certificate to ensure that they are in a satisfactory condition and fit for the service for which the ship is intended.

P – Periodical Survey: A periodical survey is an inspection of the items relating to the particular certificate to ensure that they are in a satisfactory condition and fit for the service for which the ship is intended.

R – Renewal Survey: A renewal survey is the same as a periodical survey but also leads to the issue of a new certificate.

An **Additonal survey** – is an inspection, either general or partial according to the circumstances, to be made after a repair resulting from investigations or whenever any important repairs or renewals are made

Reg. – Regulation

ISPS – International Ship and Port facility Security code

ISM – International Safety Management

MODUS –

HSC – High Speed Craft

IBC – International Certificate of fitness for carriage of dangerous Chemicals in Bulk

IGC – International Gas Code ??

INF – Irradiated Nuclear Fuel

HSSC – Harmonized System of Survey and Certification

IM – InterMediate

NO_X –

CHAPTER 7

Structural arrangement

QUESTIONS:

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1 Cargo holds

Cargo holds are in general large, empty, rectangular spaces where there are as few stiffeners as possible exposed to the cargo (frames, longitudinals etc.). Only in single-hull bulk carriers, old ships like single-hull tankers and dry-cargo ships, can the cargo be in direct contact with the ship's shell plating. Nevertheless, the hold is so important that the entire ship's construction is aimed at enabling the moving of the hold and its contents (the cargo) through the water from port to port.
The amount of cargo carried determines the earning capacity of the ship. The bulkheads of the holds are as flat as possible to make them "user-friendly".

Hold seen in the aft direction (heavy lift - / multipurpose ship)

Bulk carriers
In bulk carriers the surroundings of the tank top in the holds, not under the hatch opening, **slope upward**, so that the cargo slides down towards the area where the grab can take it. Also, these ships have an increased tank top plate thickness to compensate for the wear damage caused by grabs.

1.1 Multipurpose ships

In multipurpose ships, the ship owners prefer just one very large hold. The crew can then decide on the basis of the type of cargo how to subdivide the hold. The hold is divided by **movable bulkheads** positioned either horizontally or vertically. The bulkheads can be


Cargohold of a capesize bulker, self-trimming, corrugated bulkhead, double hull, with a bulldozer to move the cargo under the grab.

attached to the sides of the hold in a very simple manner. Legal safety requirements (intact damage stability) normally require that one or more of these movable bulkheads are always in place. The actual number of division-bulkheads depends on the length of the ship.

Both the side longitudinal bulkheads (the boundary between hold and wing tanks) and the tank tops have manholes to enable access for inspection of the tanks. The longitudinal bulkheads have lashing points for cargo securing. Heavy cargo is often sea-fastened temporarily by means of beams and / or brackets welded to strong points in the ship's side and tank top. This can, of course, only be done when the tanks are safe for hot work.

The humidity in the holds can be controlled by ventilation, recirculation and / or the use of dryers.

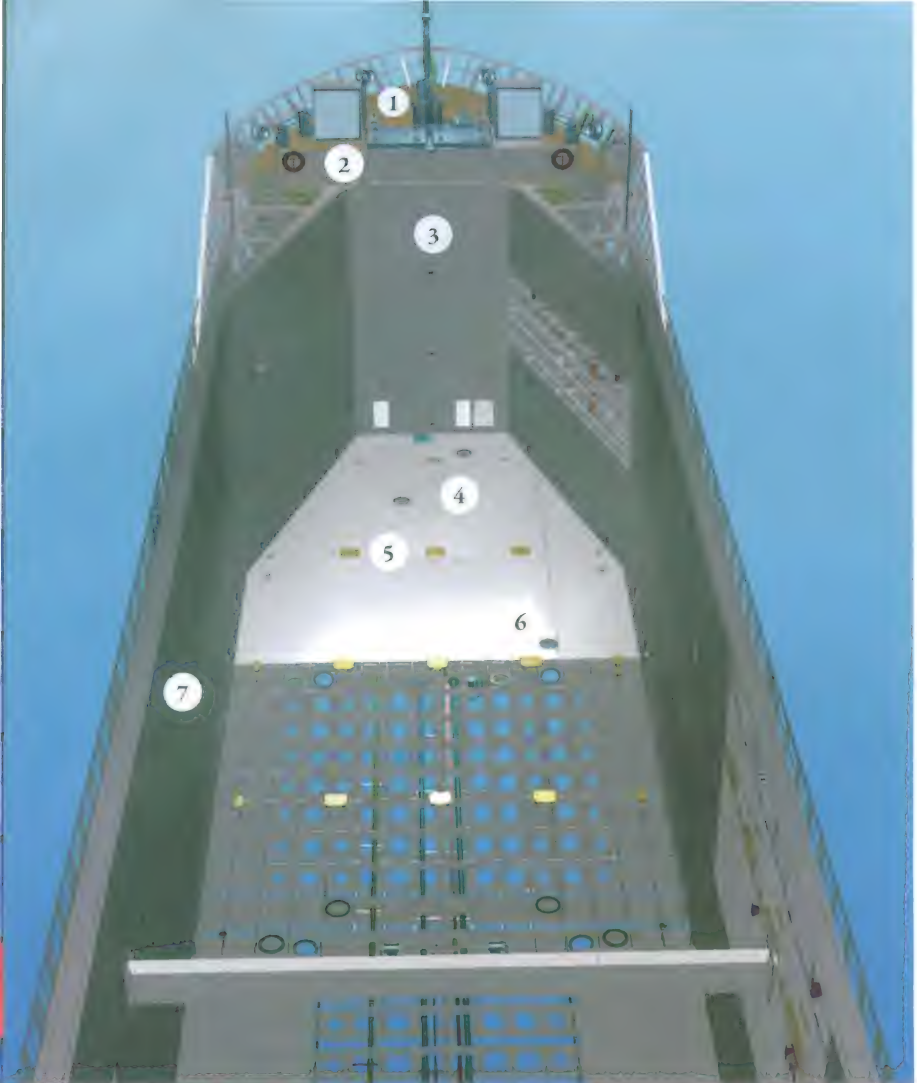
Most multipurpose ship cargo holds are **box-shaped**. This means that the hold is rectangular and the spaces have straight walls. This is important when containers have to be carried as cargo. If the hatches and the holds have a facility to lash containers, the holds are then said to be **"container fitted"**.

The ship in the pictures shown is designed to load wood, in box-shaped parcels. The design is optimized for loading these parcels, with a minimum loss of space. The hatch-covers are trapezium-shaped, with external stiffening, so that another tier of parcels can be loaded in the space created by the shape of the hatch cover. A disadvantage is, that the ship cannot take deck cargo.

Particulars of the hold:

Length	*49.7 meters*
Width	*10.0 meters*
Height of the coaming:	*2.33 meters*
Max. depth	*8.85 meters*
Capacity	*149,300 ft^3*
	= 4228 m^3

Cargo hold of a heavy-lift ship.

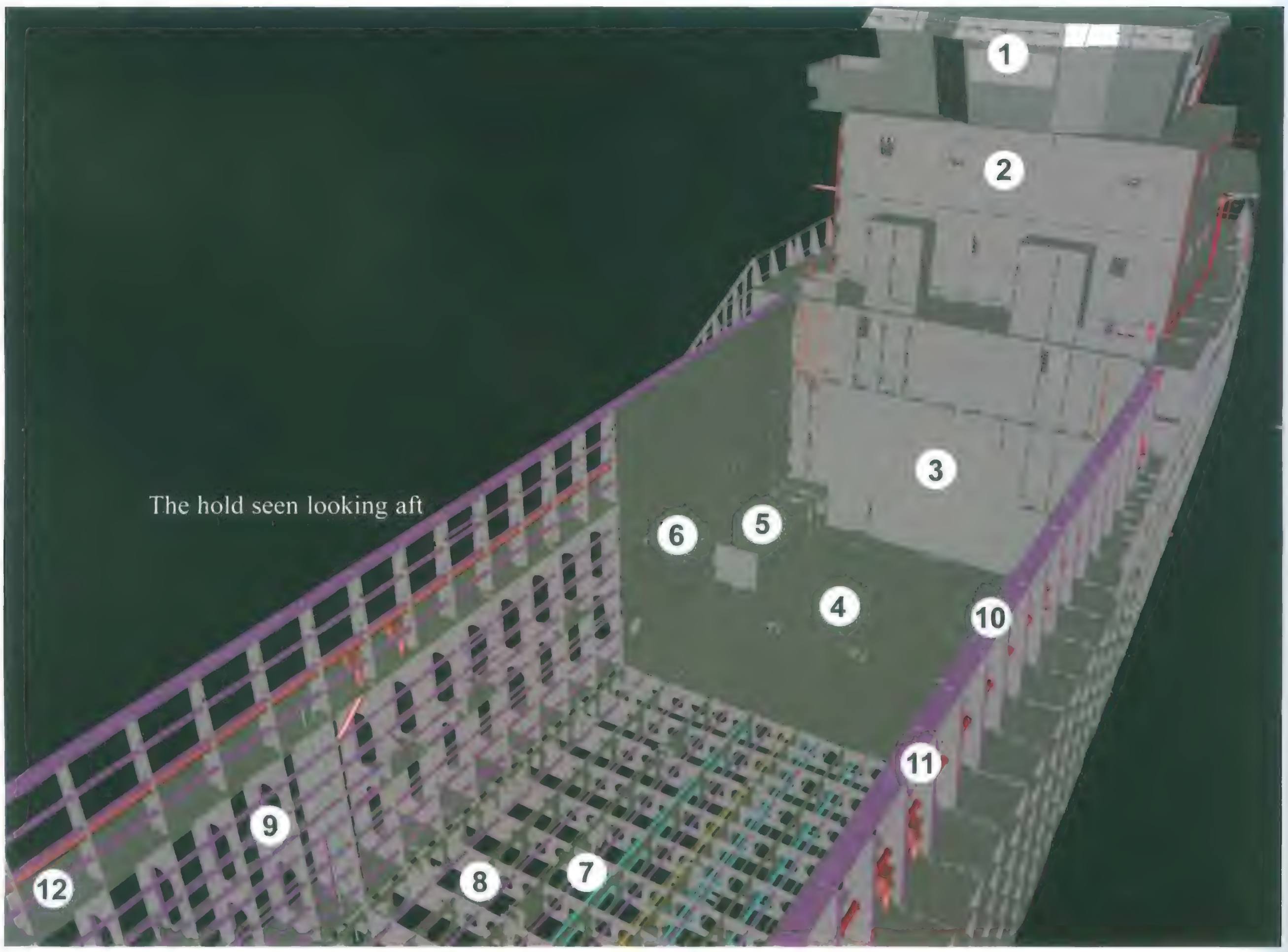


Explanation of the image to the left:

1. Forecastle deck
2. Breakwater on the focsle deck
3. Bulkhead
4. Tank top
5. Holes for fitting containers
6. Manholes, entrances to double bottom
7. Longitudinal bulkhead between hold and wing tank

Explanation of the image below:

1. Bridge
2. Deckhouse
3. Engine-room bulkhead
4. Tank top
5. Ballast tank shaped to make the hold box shaped
6. Longitudinal bulkhead wing tank
7. (full) Floor (plate)
8. Side girder
9. Web frame
10. Toprail
11. Coaming
12. Gangway / Main deck



The hold seen looking aft

1.2 Container Feeder Ships

The holds on cellular container ships are divided into multiple cells, each capable of storing a stack of 20' or 40' containers in a fore and aft direction. The spaces (cells) are separated from each other by guide rails. During loading and discharging the containers are guided by the vertical rails. In addition, the rails also keep the containers in place.

Because of the small depth, which keeps the tonnage figure low, container feeders have more containers on top of the hatch covers than inside the holds.

1.3 Tankers

When ships are designed to carry liquid cargoes in bulk, they are called tankers. The total cargo space is then divided by watertight bulkheads into a large number of separate tanks.

Each tank (in oil tankers) is provided with:
- entrance hatch
- escape hatch
- tank cleaning hatches
- ladder to descend in the tank
- ullage and/or sounding pipe
- ventilation / de-aeration pipe (closed system)
- filling and discharge lines
- (deep-well) pump, depending on the kind of cargo
- dipping holes.

View of a tank on a chemical tanker

Every tank has possibilities for:
- temperature measurement, ullage and / or sounding measurement, often radar level control,
- heating possibilities to control the cargo temperature,
- independent high level alarm (95% full) and overfill alarm (98% full).

  tank cleaning with fixed or hand operated washing machines.

Normally the internal surfaces of cargo tanks are **coated** with a paint which is resistant to the cargo the ship has been designed for or constructed of stainless steel. Furthermore, and depending on the size of the ship, there are additional deck holes for transport of materials, tools, or in case of an accident, for people.

The tanks have as little stiffening inside as possible to prevent the accumulation of dirt and sediment, and to minimize the area to be expensively coated.
Crude tankers only have the deck head and bottom coated. Inert gas protects the steel generally. No oxygen - no rust.

The surrounding ballast tanks are also stiffened where possible. Division-bulkheads between cargo tanks are therefore, often corrugated to minimize stiffening; however, stringers and some brackets are still needed.

The picture on this page shows the insides of a tank on a chemical tanker (GT 3350, deadweight 5070 tons). The transverse bulkhead is a **corrugated** bulkhead.

1. Corrugated bulkhead (transverse)
2. Stringer
3. Main deck
4. Center line corrugated bulkhead
5. Section of the web frame

Cargo tanks are provided with simple ladders for inspections, cleaning, maintenance etc. The entrance is usually a small hatch in the upper deck.

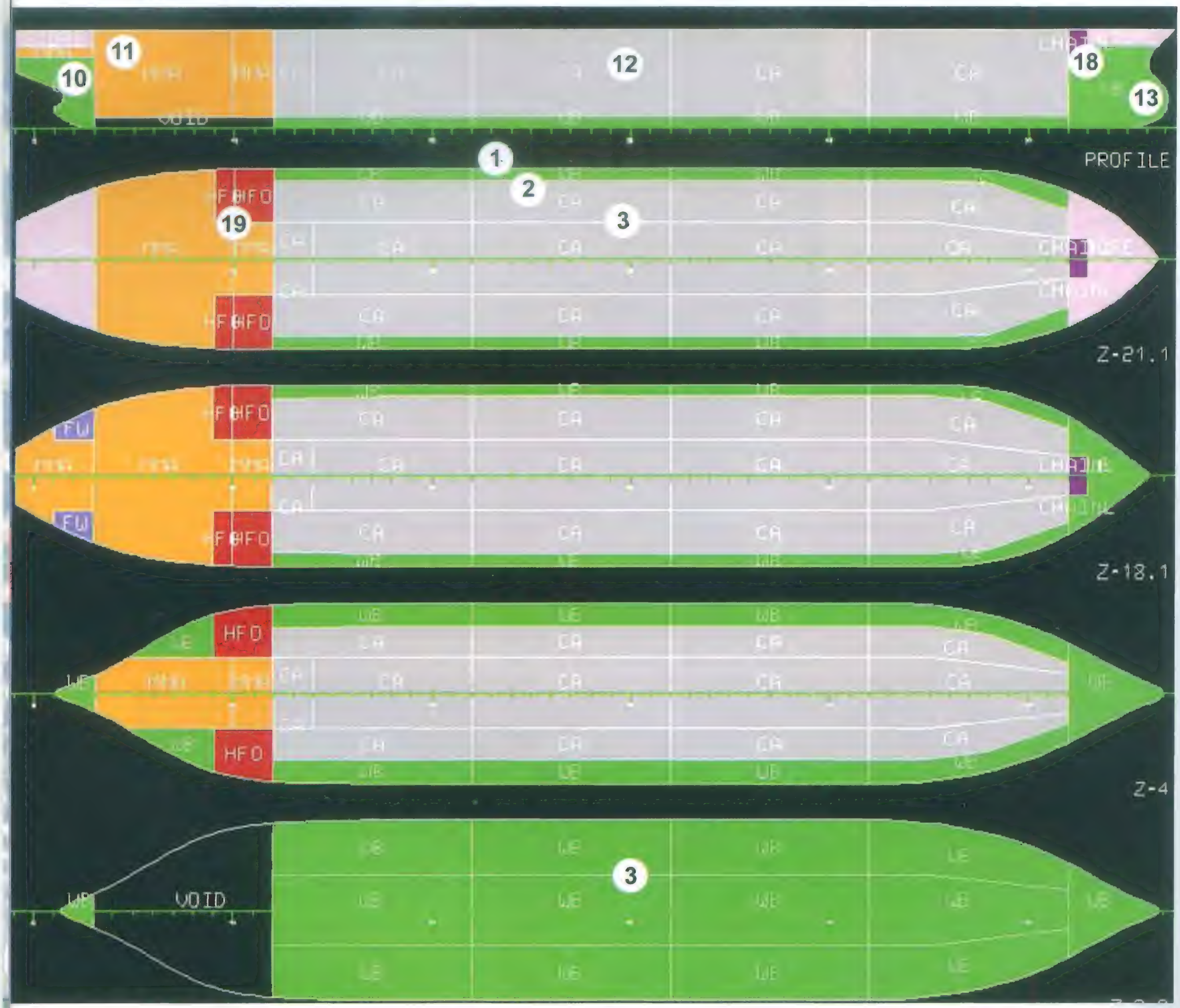
The hold can be inspected by entering via the entrance hatch and a simple ladder. The double bottom slopes slightly towards the center plate, to facilitate the flow of liquids to the suction of the pump.

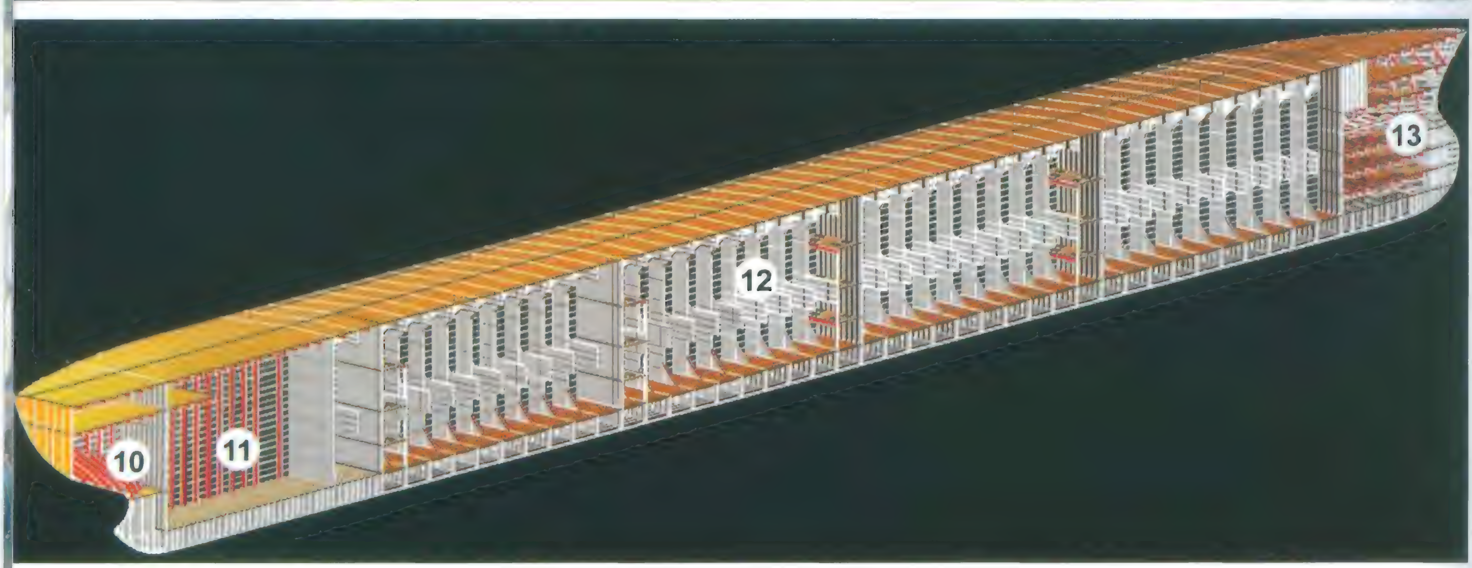
Ullage is the distance between the cargo liquid and the top edge of the entrance hatch, (or another decisive level) on which the tank content tables are based. In dry-cargo ships it is simply the space between the cargo (such as grain), and a measuring point on deck.

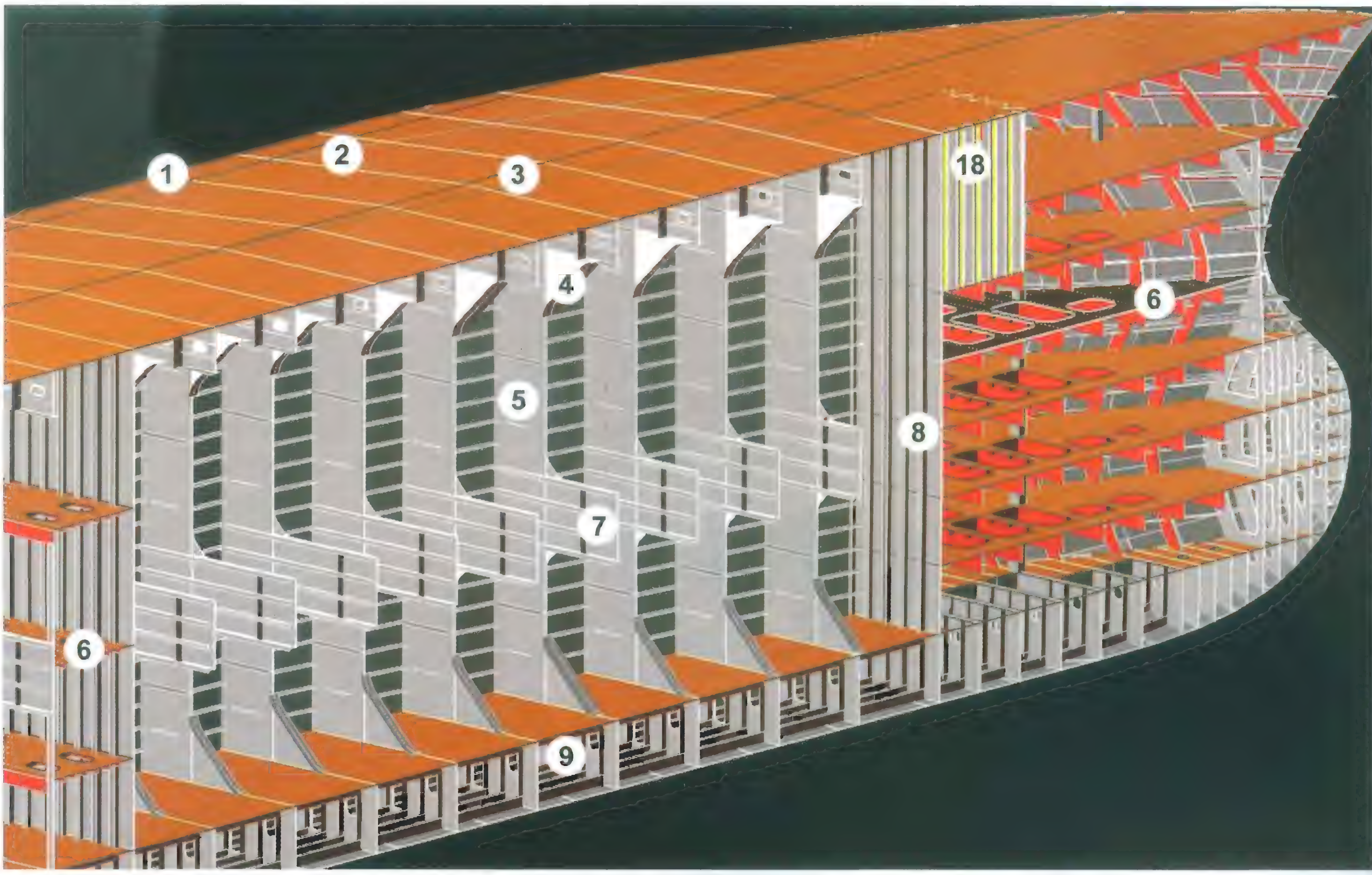
Double hull tanker

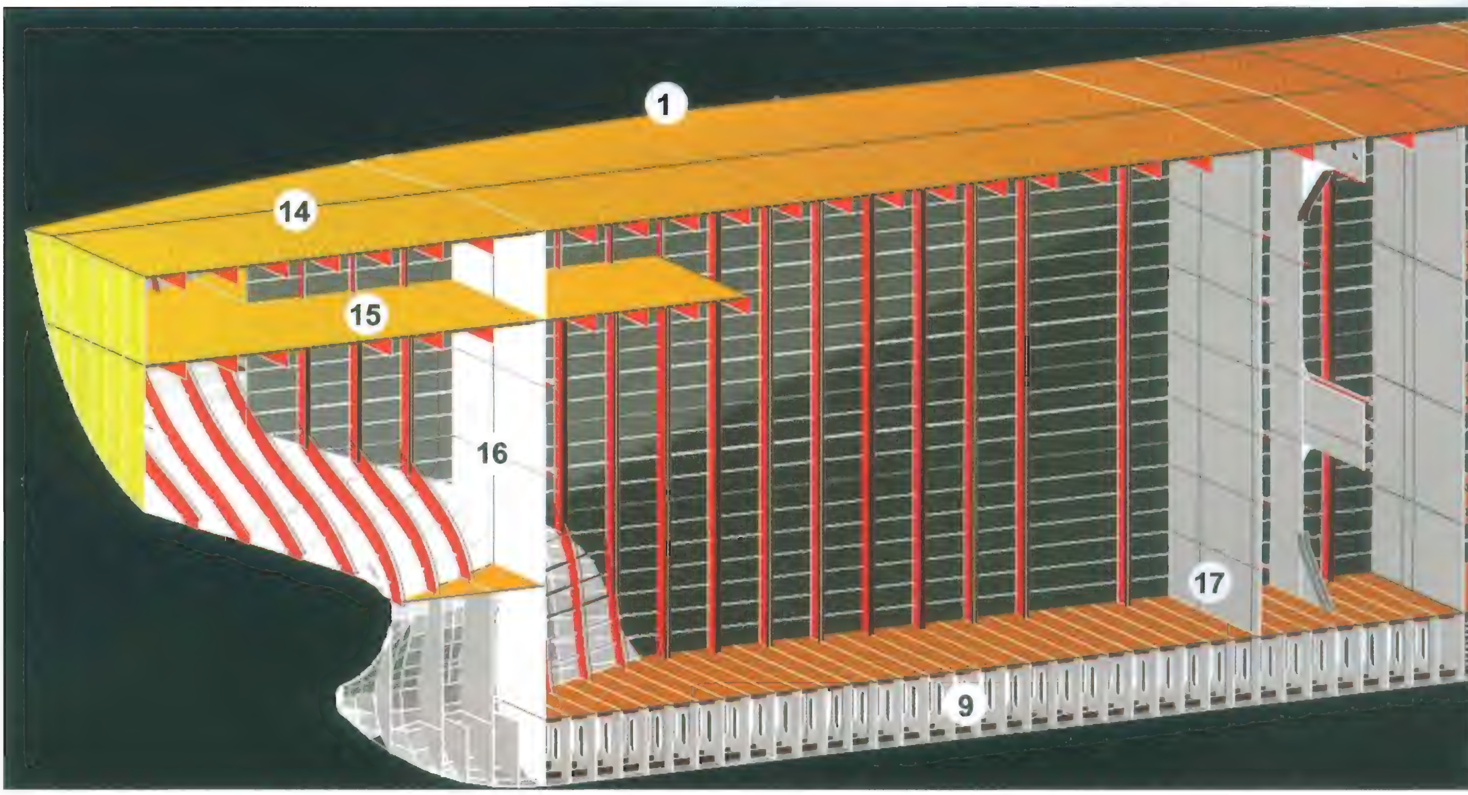
These images are of a double hull tanker, whose main dimensions are approximately:

deadweight:	150 000 tons
length over all:	292 meters
maximum breadth:	46 meters
draft:	16 meters









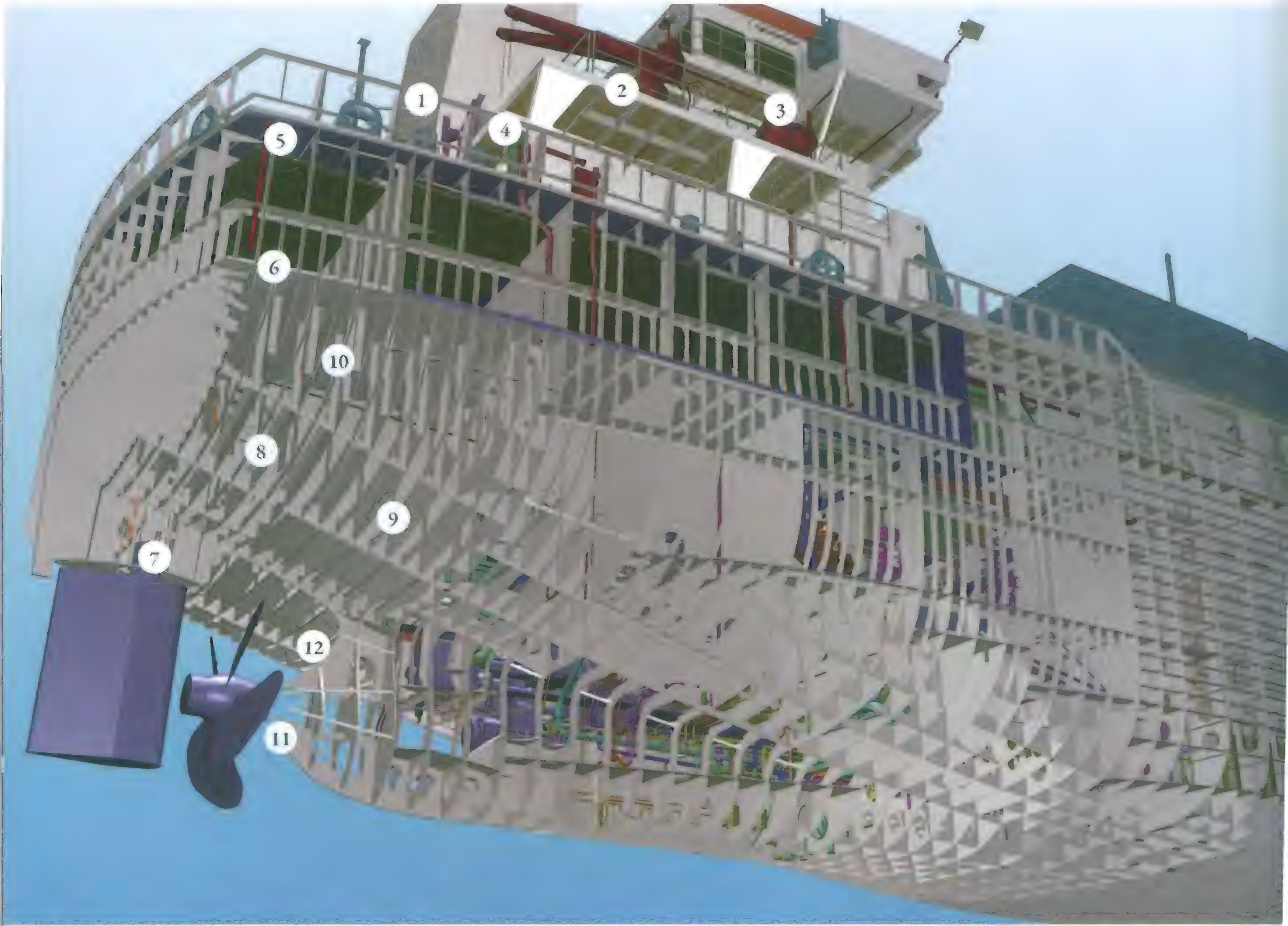
1. Outer side shell (below deck)
2. Inner side shell (below deck)
3. Longitudinal bulkhead (below deck)
4. Bracket
5. Web frame
6. Bulkhead stringer
7. Cross-tie
8. Fore peak bulkhead
9. Double bottom
10. After peak
11. Machinery space
12. Cargo tanks
13. Fore peak tank (water ballast)
14. Upper deck
15. Steering gear room / Flat
16. Aft peak bulkhead
17. Engine room bulkhead
18. Chain locker
19. Fuel bunker

2 Stern

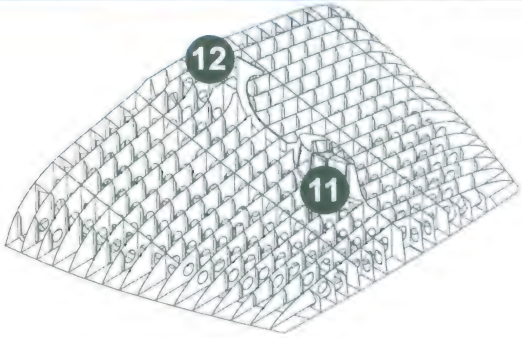
Most cargo ships have the accommodation and the engine room as far aft as practicable. The accommodation is above the engine room, and by installing it all the way aft, the shafting is as short as possible. The parallel mid-body is available for cargo in this configuration.
The aft part, V-shaped, still allows the various engine parts to be fitted. The working places, storage facilities and most fuel tanks are also found aft.

The aft peak is the part of the ship that is enclosed by the aft peak bulkhead, the stern, shell, transom and the aft deck. It is the part of the ship, usually a ballast tank, where the stern tube is located, with the tail shaft, driven by the main engine, running through, providing cooling for the stern tube.
The stern tube is supported by high floors, above shaft level. These high floors, at every frame, also have to sustain any propeller induced vibration.

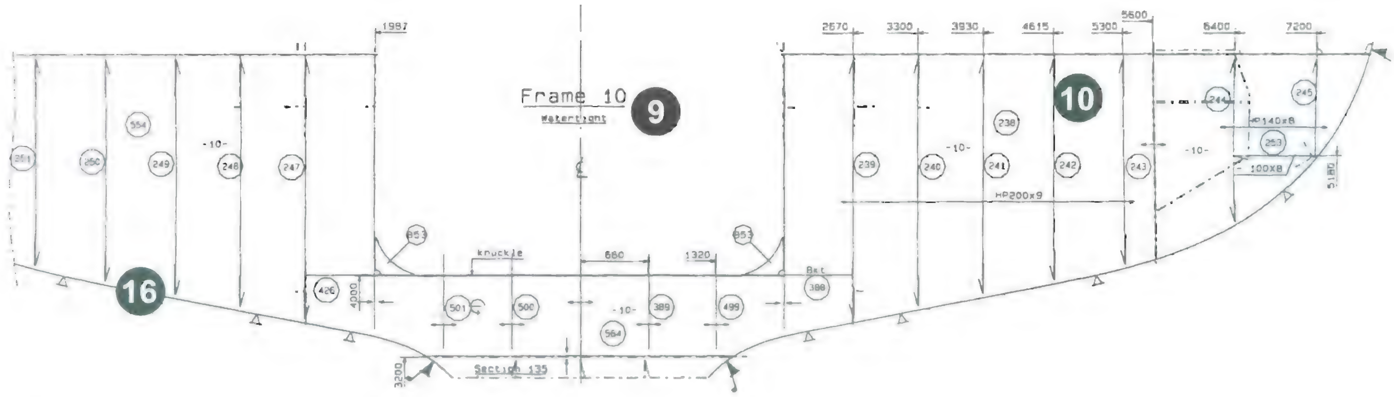
The stern section is the section above the aft peak where the steering gear is located. The **rudder carrier** is located at the steering flat, taking the weight of rudder and rudderstock or kingpost. The kingpost runs through the rudder trunk (frame 0) through the upper part of the aft peak. The **transom** borders the aft side of the stern section. This is a plate running nearly the full width of the ship, on which the name of the ship and the homeport are welded.



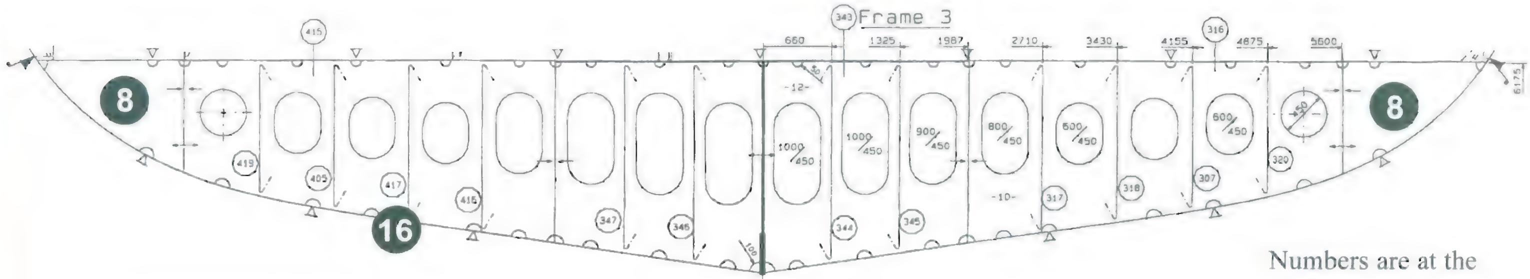
1. Funnel
2. Bridge
3. Bridge wing
4. Accommodation
5. Poop deck
6. Main deck
7. Rudder horn
8. Floor plate, frame no 3
9. Floor plate, frame no 10
10. Stiffeners
11. Center keelson
12. Stern frame
16. Bottom plate



Assembly drawing

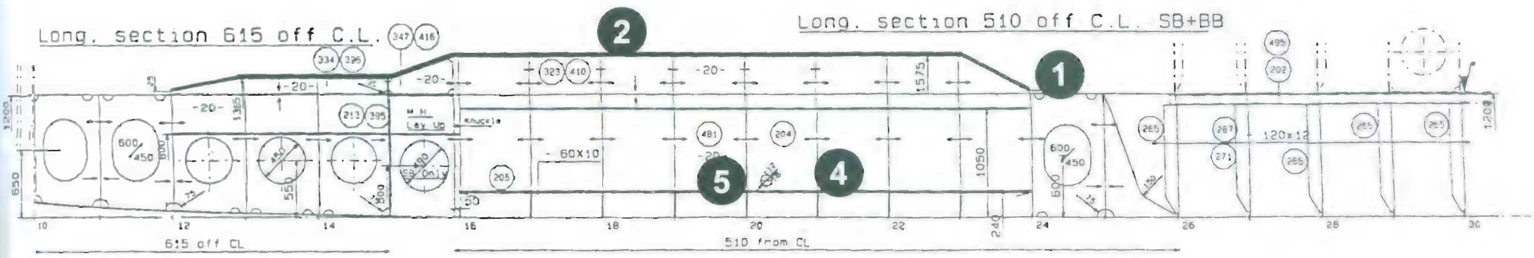


Transverse cross-section at frame 10



Transverse cross-section at frame 3

Numbers are at the previous page.

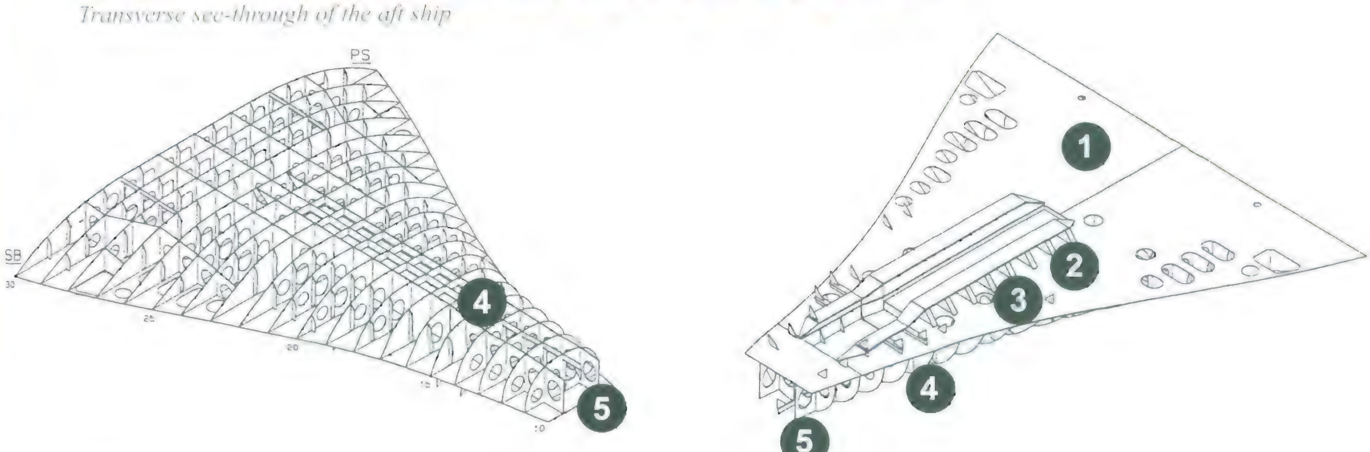


Longitudinal cross-section of the engine foundation

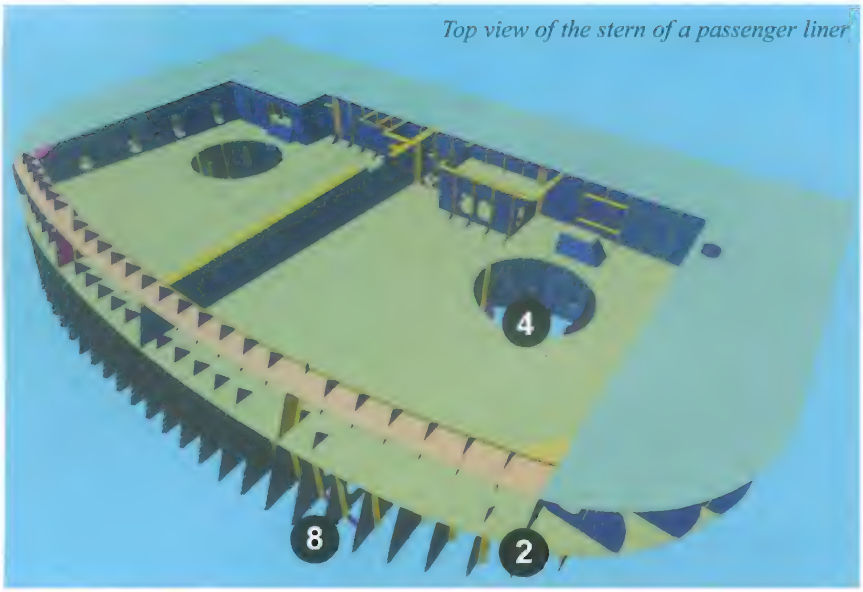

Transverse see-through of the aft ship

Explanation of the images:

1. Tank top
2. Top plate for engine foundation
3. Brackets under engine foundation
4. Floors
5. Longitudinal girders of the engine foundation



Assembly drawing of the double bottom of the engine room

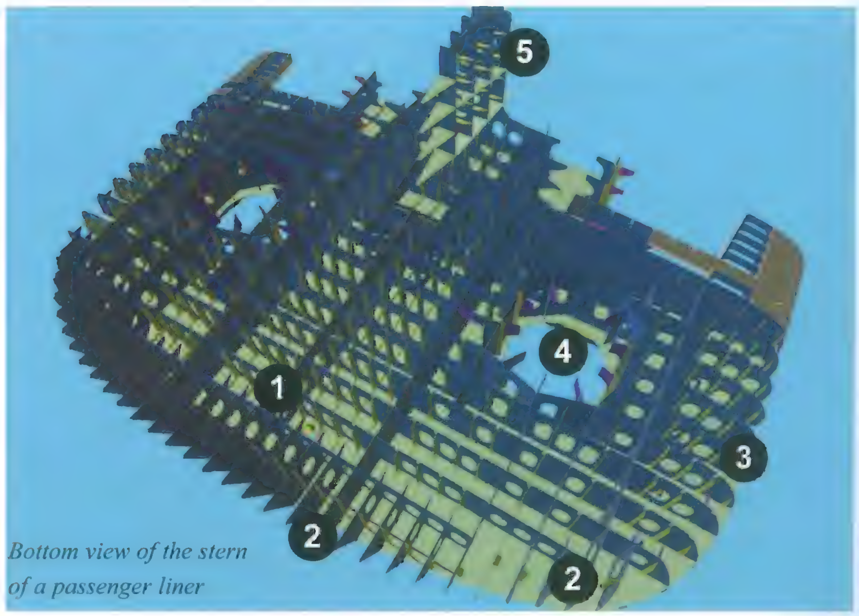


Top view of the stern of a passenger liner

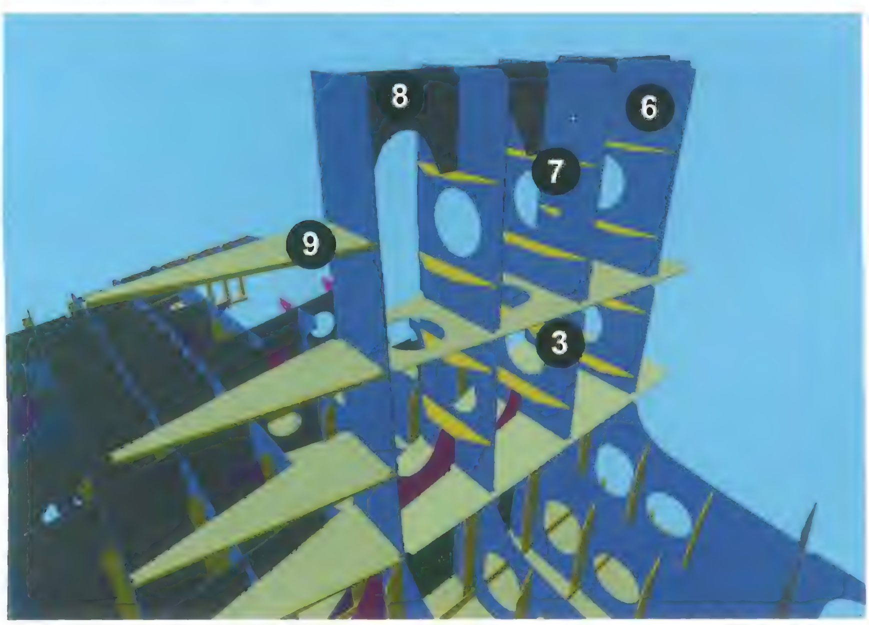
Explanation of the images on this page:

1. Center keel
2. Side girder (watertight)
3. Floors
4. Hole in the deck for the azipod (see also chapter 12)
5. Skeg
6. Floor in skeg
7. Stiffening floor brackets
8. Longitudinal floor brackets
9. Stringer brackets
10. Azipod connecting flange

Attaching the azipod to the ship

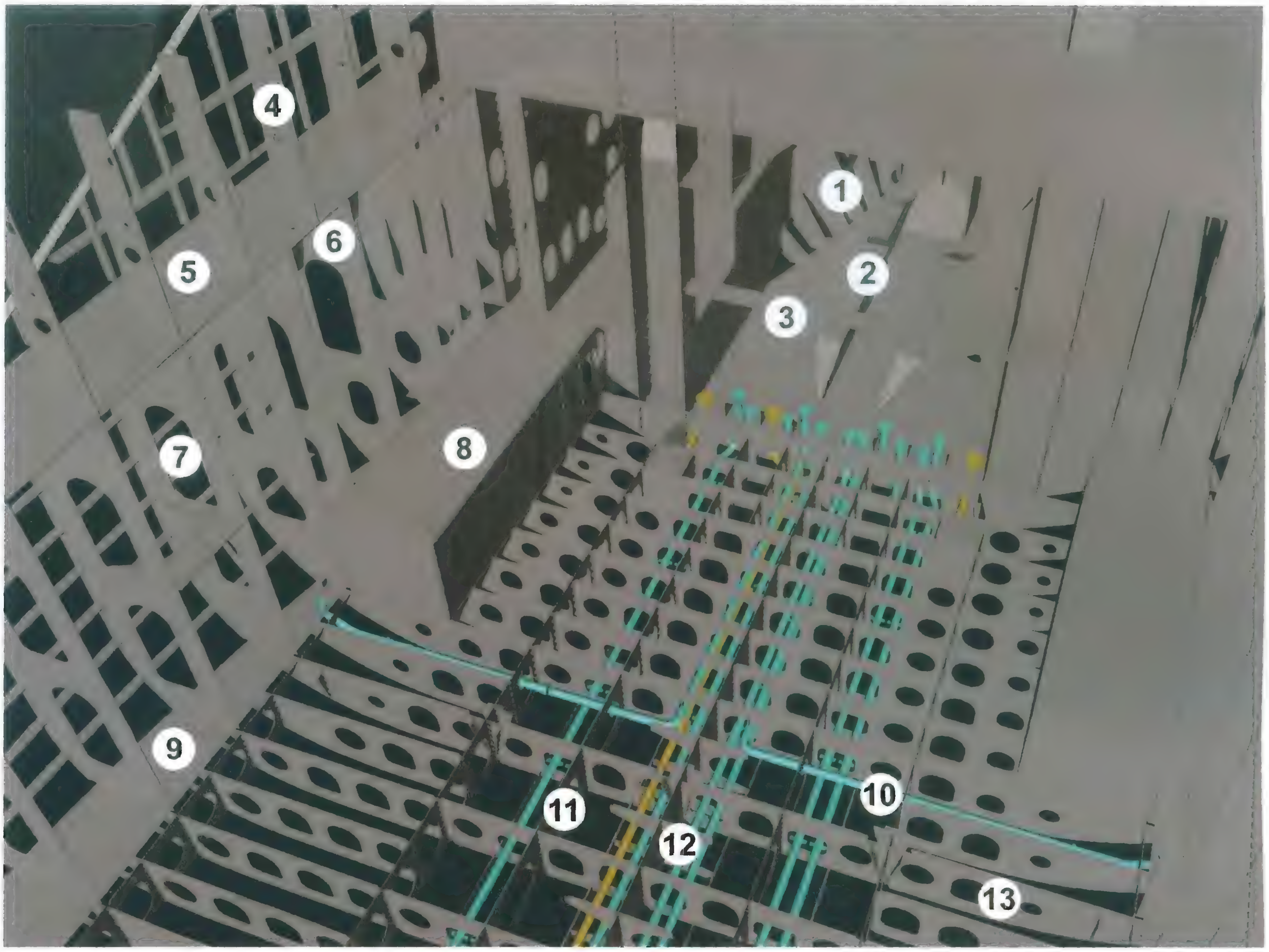


Bottom view of the stern of a passenger liner



The Skeg.

This is a narrow vertical part added to the hull in the stern. It is necessary for the course stability of twin propeller ships. The skeg improves the course stability of the ship as it enlarges the lateral area. For dry docking the skeg is important as it transfers the load of the aft part of the ship to the keel blocks.

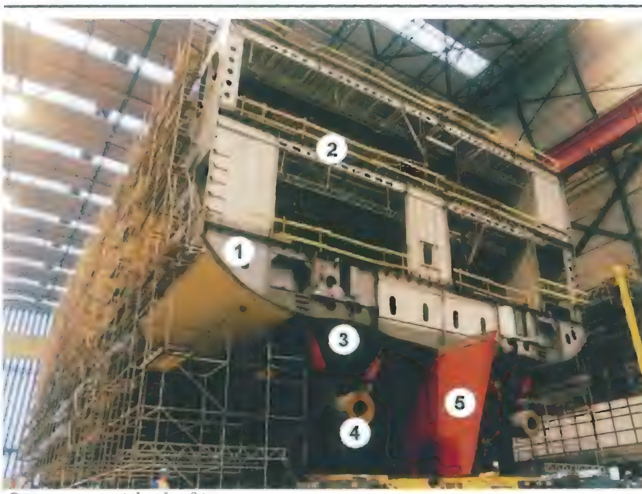


Explanation of the above image:
The ship (a container feeder), seen from aft with a glimpse of the engine room. Ballast lines come from the ballast tanks into the engine room.
The frames in the engine room double bottom run in the transverse direction and those in the wing tanks in longitudinal direction.

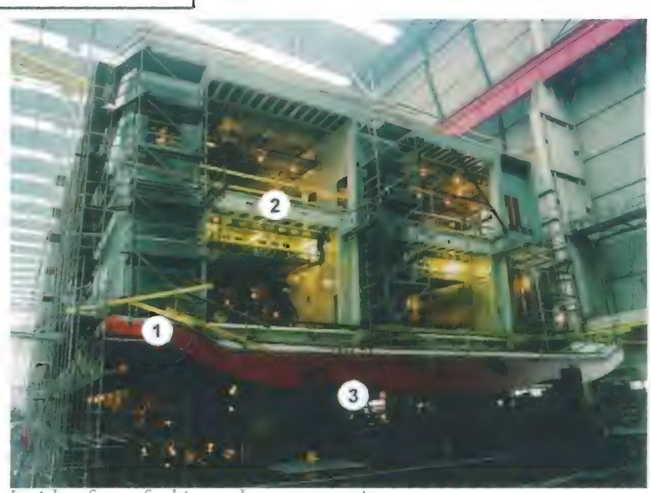
1. Web frame
2. Top plate engine foundation
3. Tank top
4. Coaming stanchion
5. Upper deck
6. Web frame
7. Longitudinal framing
8. Water or oil tank
9. Bottom wing tank
10. Delivery suction line of wing tank
11. Side girder
12. Center keel plate
13. Full floor (plate)

The pictures below show views from aft of two Roll-on Roll-off vessels. The open access spaces can be closed by ramps (not yet in place). When the ramps are opened, they can be used to load or discharge moving cargo.

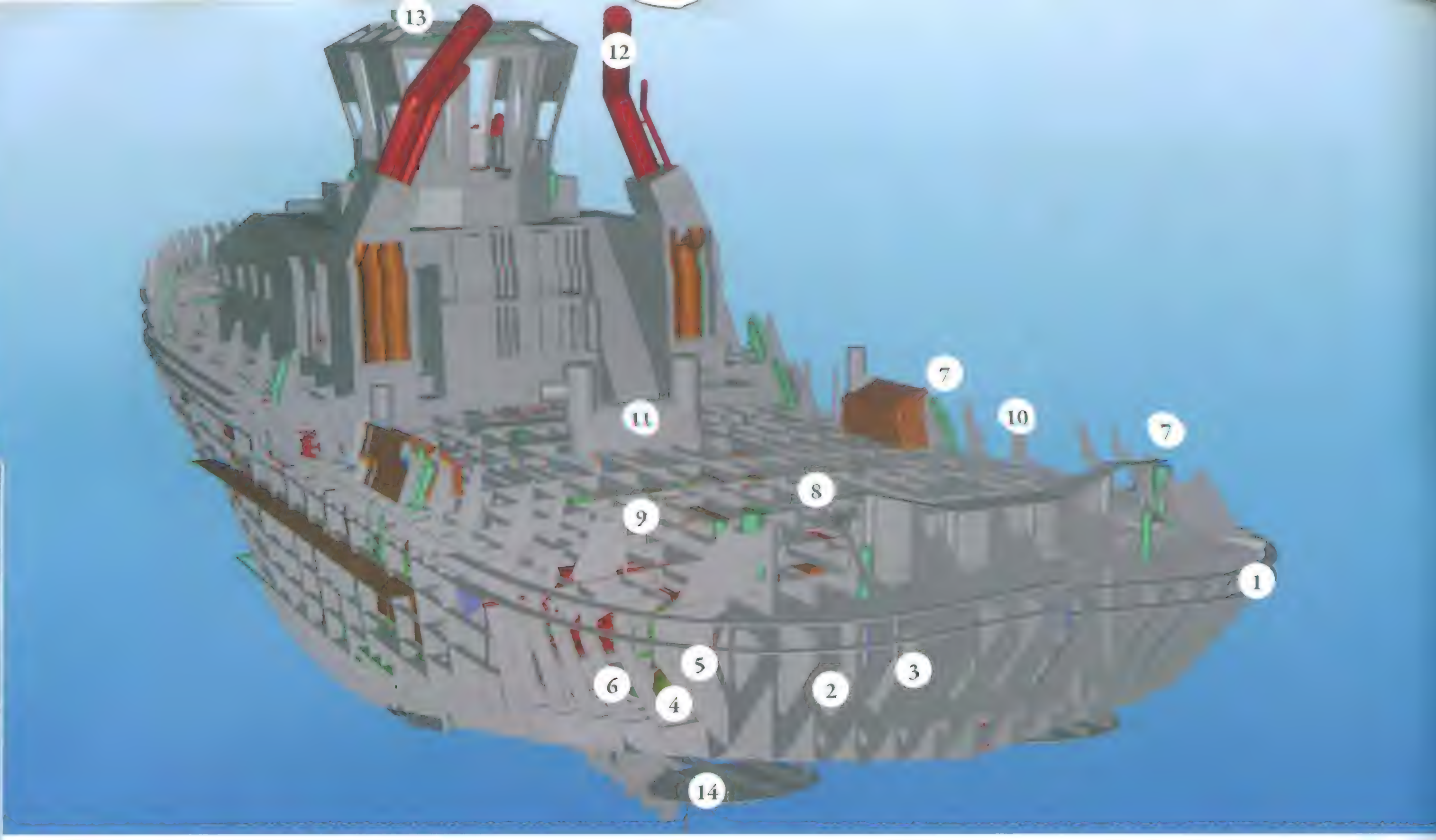
1. Freeboard deck
2. Main deck
3. A-frame, space for the propeller clearance
4. End of shafting
5. Skeg



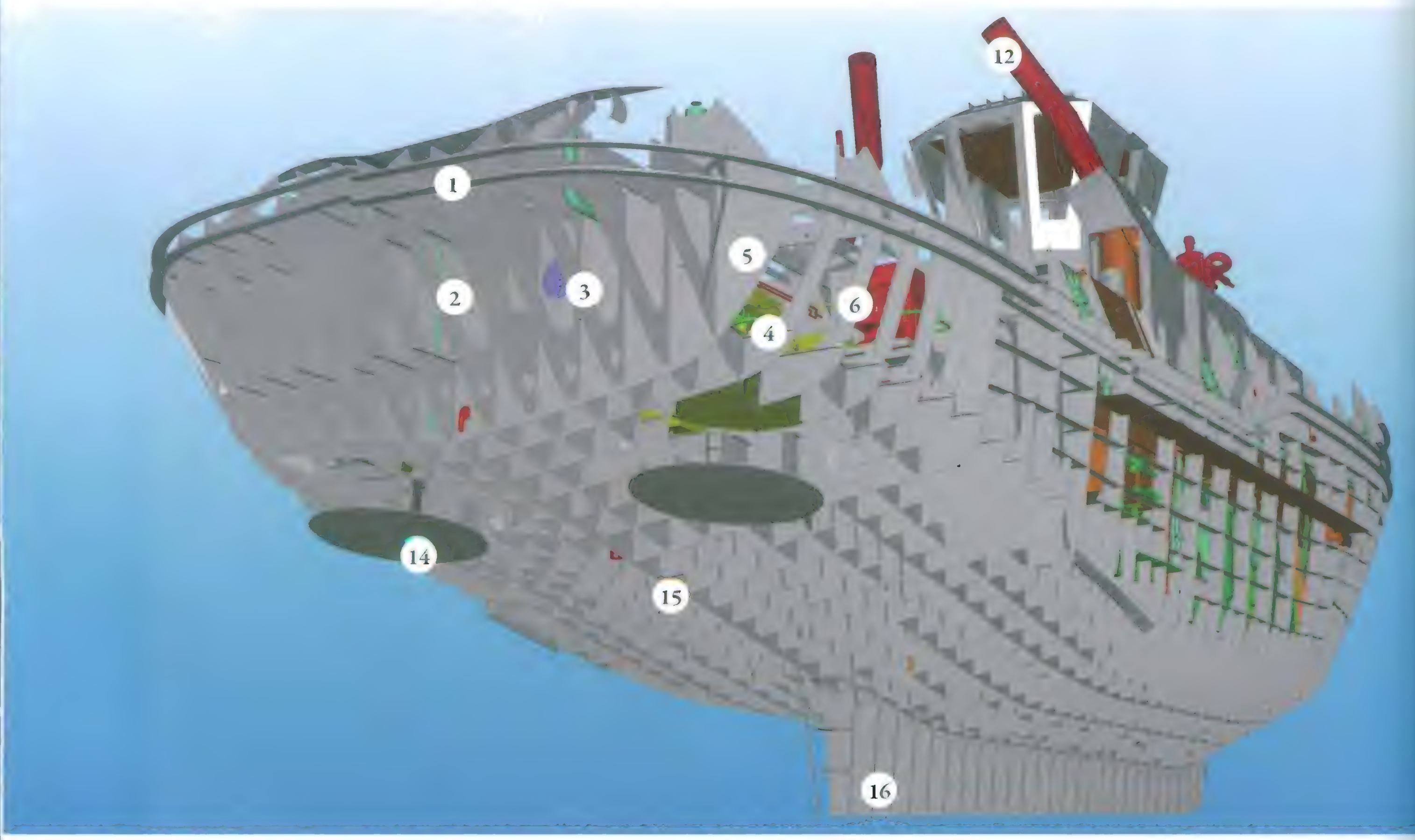
Sternpost with shafting

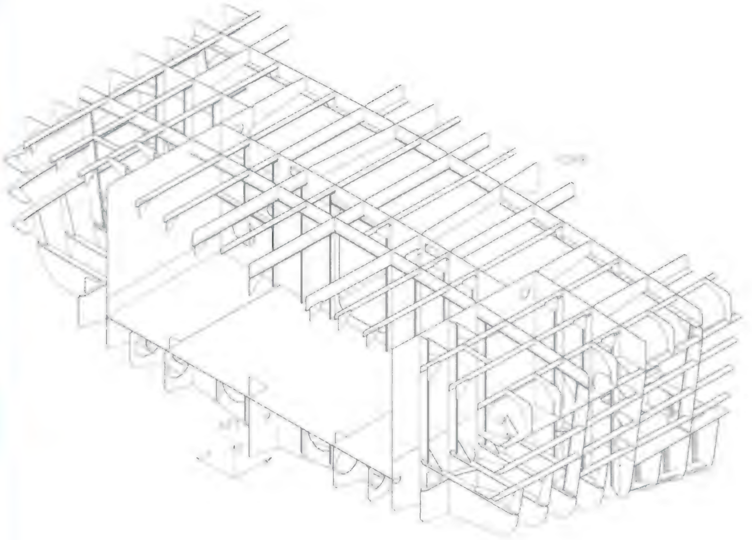


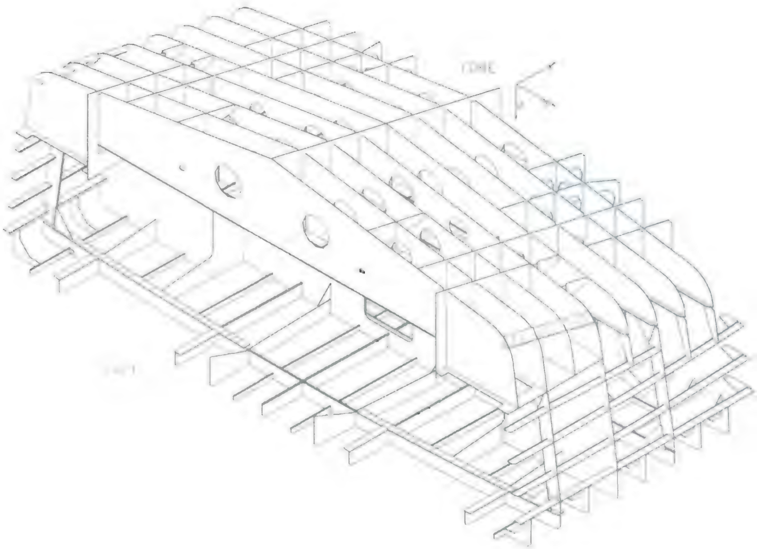
Inside of an aft ship under construction

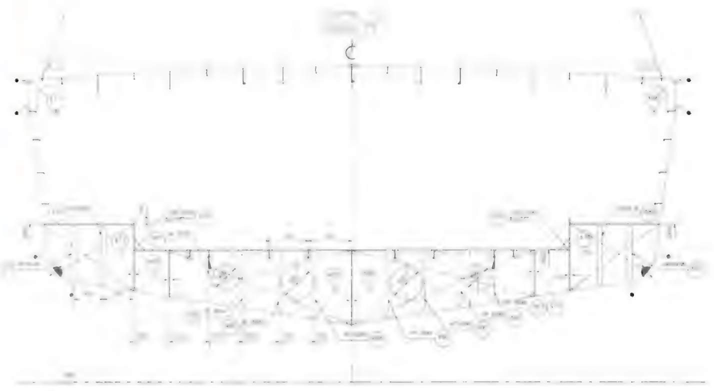


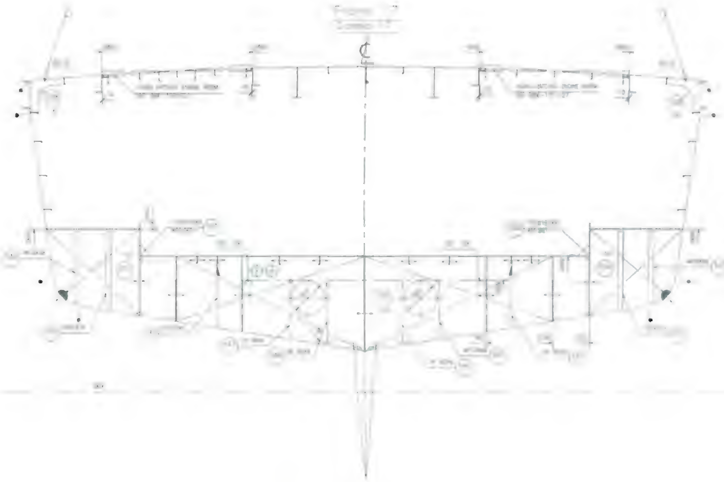
1. Fender channel
2. After peak
3. Stern brackets
4. Steering gear room (thruster room)
5. Watertight bulkhead
6. Transverse frame
7. De-aerating or vent pipes
8. Deck girder
9. Deck longitudinal
10. Bulwark bracket
11. Towing bitt
12. Exhaust pipes
13. Wheelhouse top
14. Thruster location
15. Keel
16. Skeg











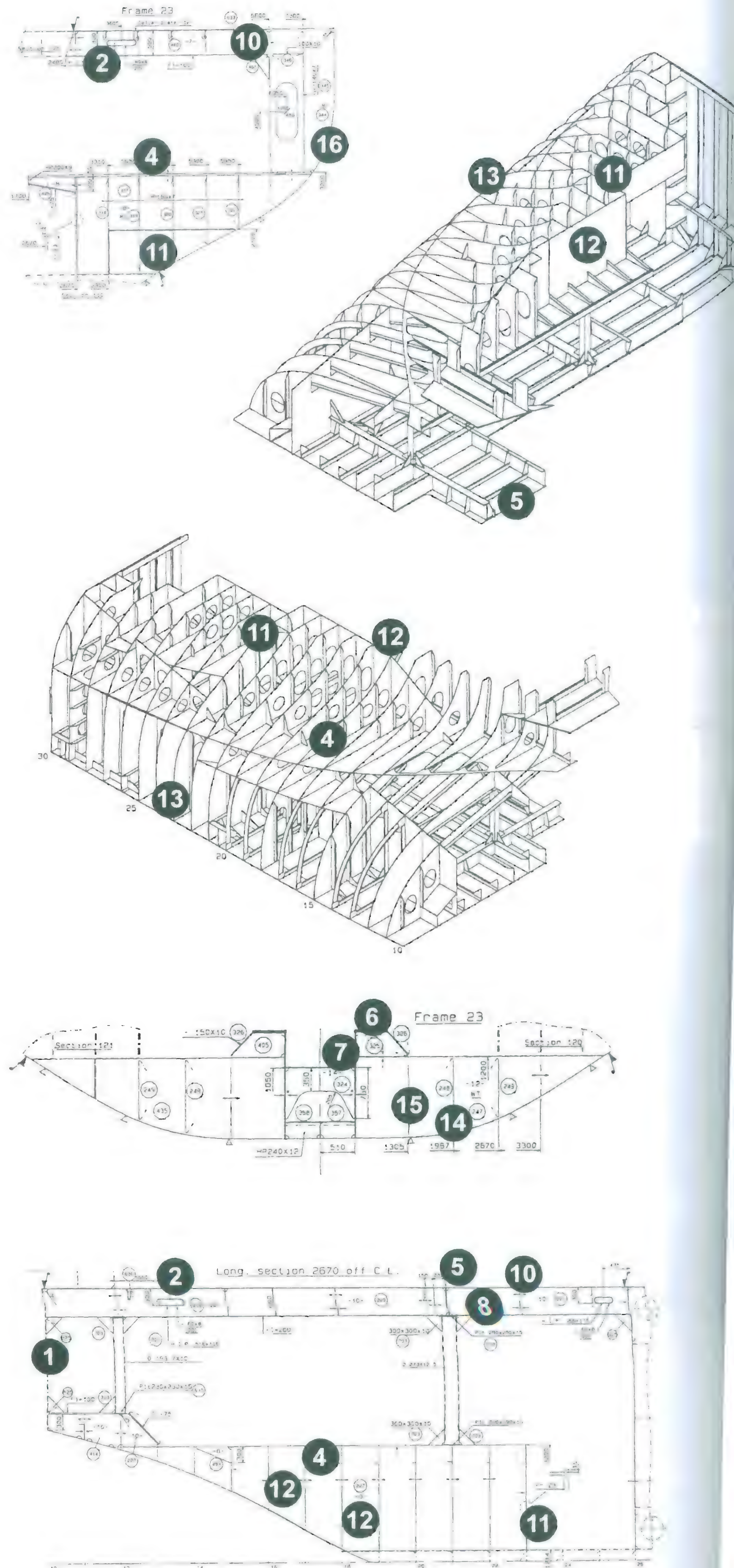
3 Engine Room

The engine room is a compartment that spans the full width of a ship in most cases. In tankers and bulk carriers, however, there are often bunker tanks in the sides, still leaving sufficient space for the engine room parts. Watertight bulkheads are located at the aft and forward ends of the engine room.

The engine room casing runs vertically towards the funnel above part of the engine room. Through the casing run the exhaust gas lines of the various diesel engines and the boiler(s). Part of the casing is closed by an access hatch, allowing transport of engine parts when opened or completely removed. Travelling cranes are installed above the main and auxiliary engines with simple manual hoists or electric hoists capable of lifting piston heads and pistons.
The large open engine room space is stiffened with deep frames, flats and pillars to withstand the water pressure from outside, the weight of the engines and the vibration induced by them.

Foundations supporting the main and auxiliary engines have to transfer the weight of the relevant machine, the induced vibrations and resulting stresses onto the ship's structure. The foundations have to keep the engines in place when the ship is rolling and / or pitching and have to be stiff to maintain a proper alignment of engine and propeller shafting. All machinery is properly bolted down and provided with sideways supports to secure their position in the heaviest ship's motions.

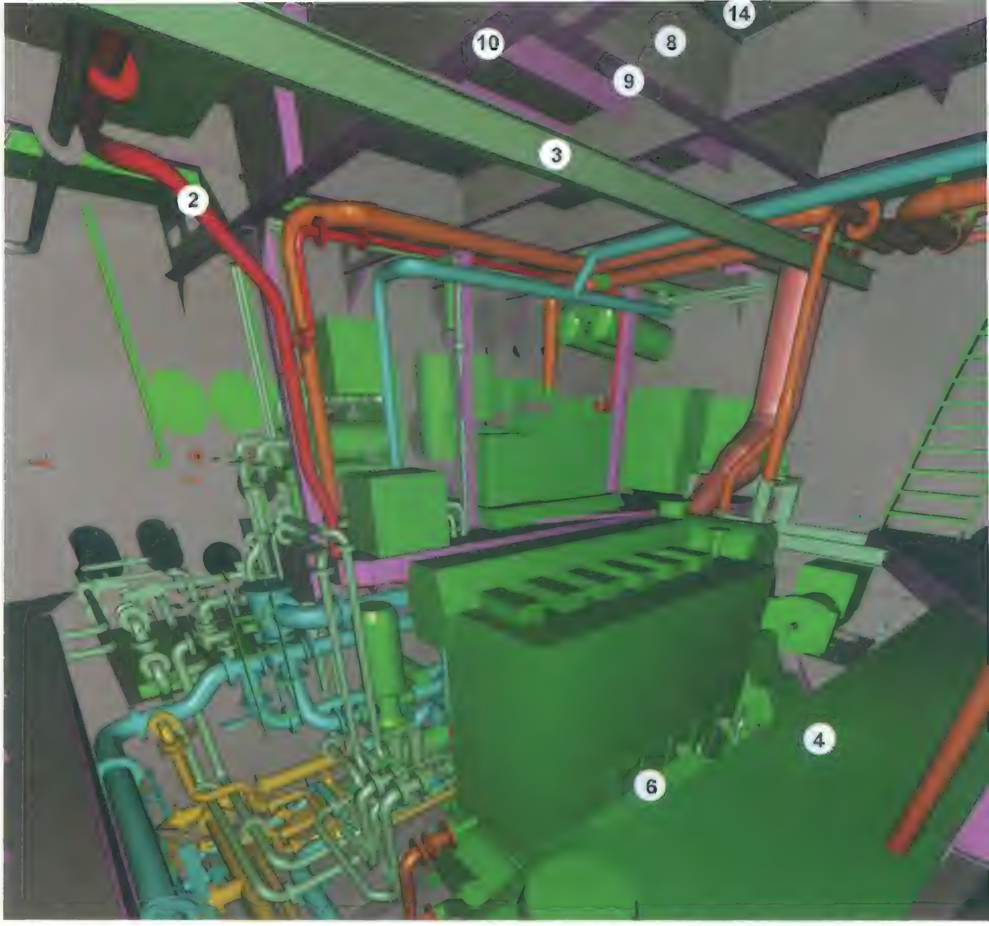
The double bottom below the engine room is often at a different level than the double bottom below the cargo spaces so that propeller shaft is at the right height. The propeller blades have to be a sufficient distance above the baseline to prevent damage.



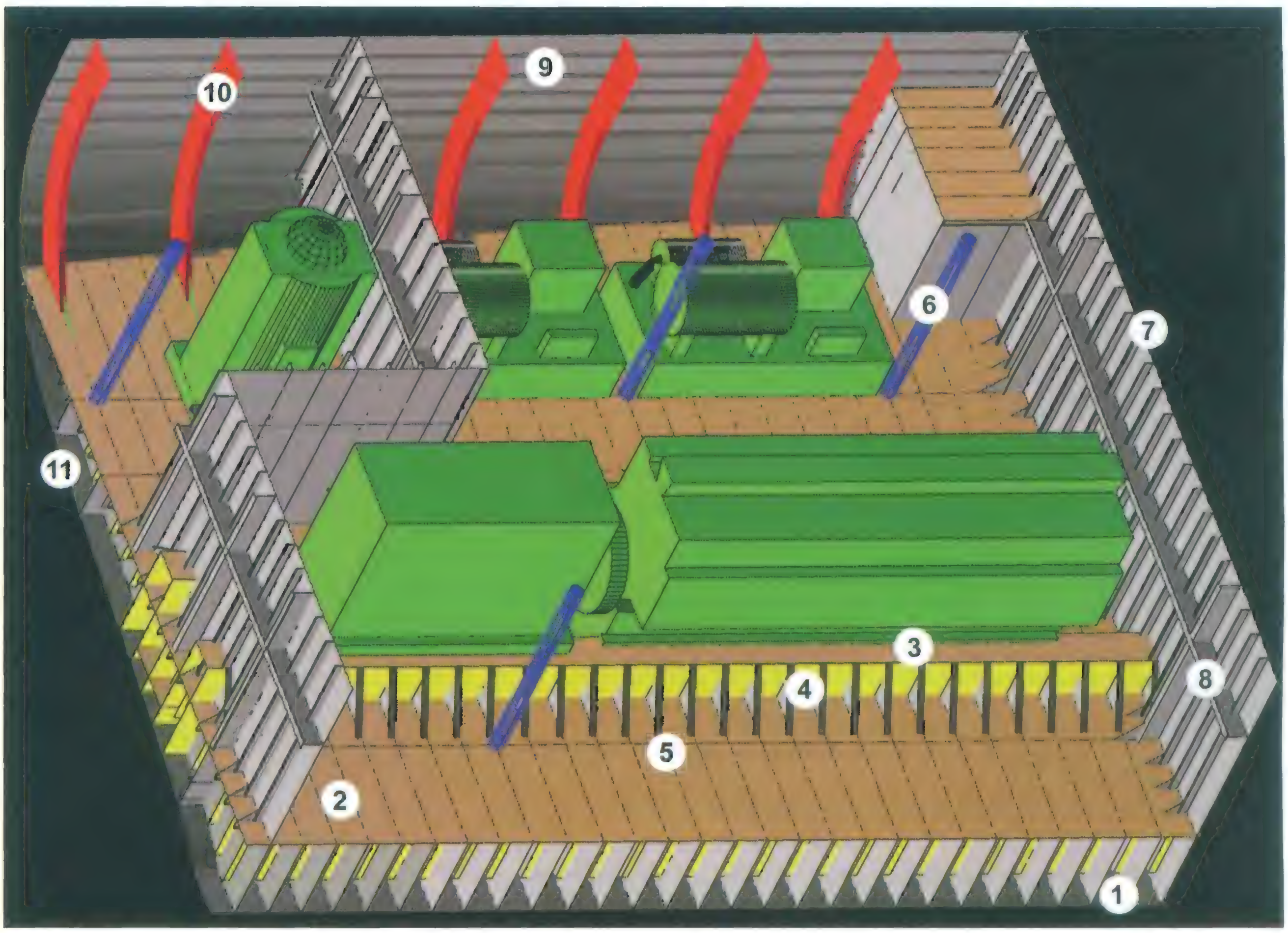
Construction drawings of the engine room of a container feeder

Explanation of the image at the right and previous page

1. Aft peak bulkhead
2. Cable guide
3. Hoist beam
4. Flat
5. Main deck
6. Top plate for the engine foundation
7. Longitudinal girders for the engine foundation
8. Longitudinal deck girder with faceplate
9. Deck girder
10. Transverse deck girder
11. Watertight bulkhead (wing tank)
12. Watertight center line bulkhead (wing tank)
13. Frame 23 (web frame)
14. Side girder
15. Floor
16. Web frame



View in the engine room of a container feeder



Explanation of the above image

1. Floors
2. Tank top
3. Crown plate of the engine foundation
4. Longitudinal girder
5. Brackets with flange
6. Pillar
7. Bulkhead stiffeners
8. Stringer
9. Side longitudinals
10. Web frames
11. Side girder

View of the down side of the double bottom. In the middle you can see the HFO-tank with heating coils.

1. Bilge plate
2. Side girder
3. Full floor (plate floor)
4. Tank top longitudinal
5. Bottom frame

4 Double-bottom and wing tanks

The double-bottom and wing tanks are discussed together as they have the same function. The wing tanks are located at the sides of the ship on top of the double bottom. Usually the two wing tanks are separated in the sense that no fluid can flow between them. Sometimes, however, the two tanks are joined in a **U-shaped** or **L-shaped** fashion.

The functions of the double bottom and wing tanks are:
- to increase the transverse and longitudinal strength of the ship
- additional safety when the bottom or side is damaged or in case of a collision (damage stability)
- to store seawater (ballast water) to position the propeller below the water surface, and the forward draft is sufficient to prevent pounding, even when the ship has no cargo on board. This is also advantageous for the stability of the vessel
- to store fuel
- to provide list and trim control to compensate for uneven loading

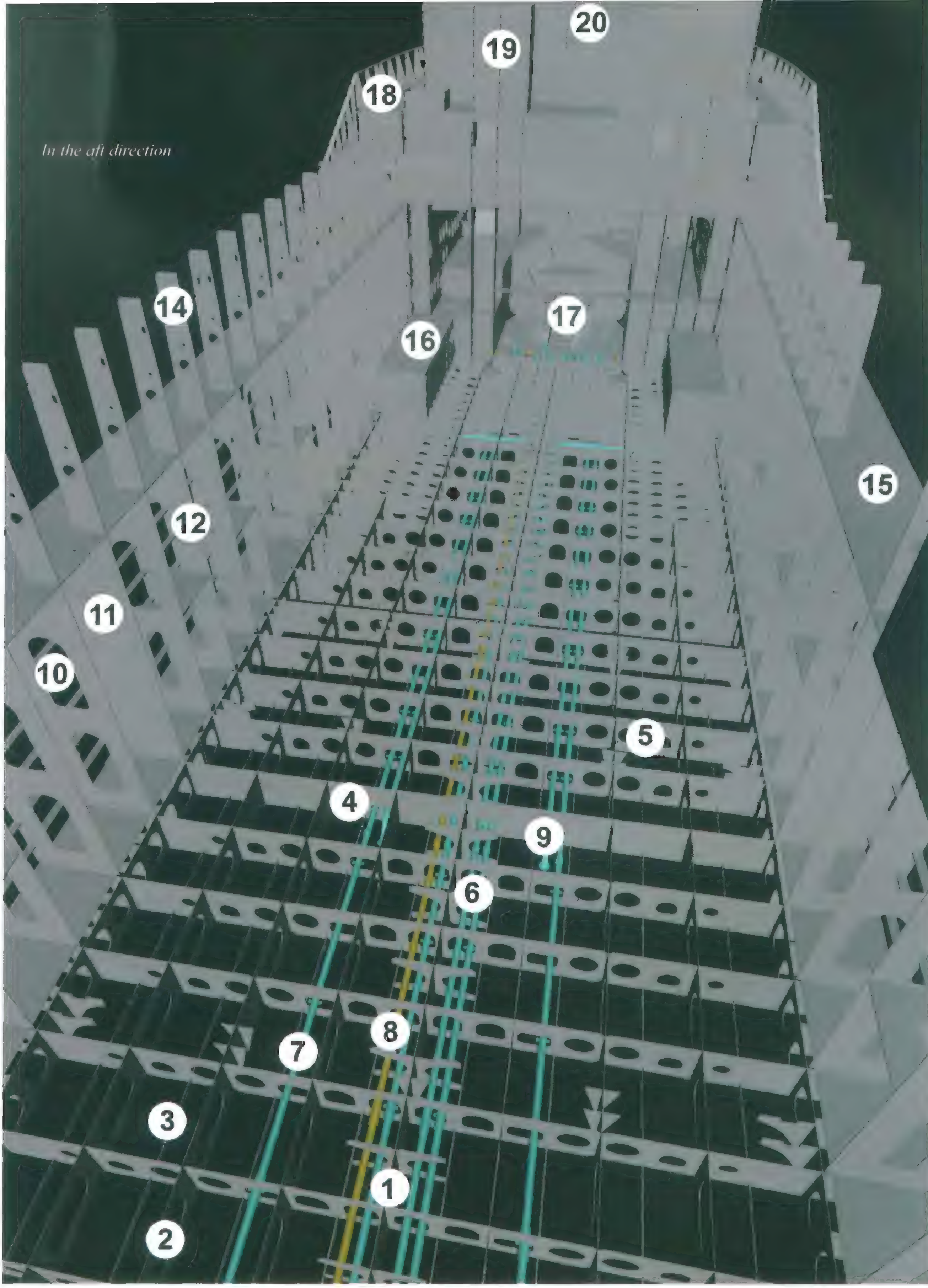
Ro-ro ships are often fitted with a heeling system. This is a system which automatically pumps ballast water from one wing tank to the opposite wing tank very quickly, to compensate for a list due to cargo.

Tanks are by definition **watertight compartments**. In the double bottom, the separation of the two sides is accomplished by the center keel or side girders fore and aft and by a watertight floor in the transverse direction.

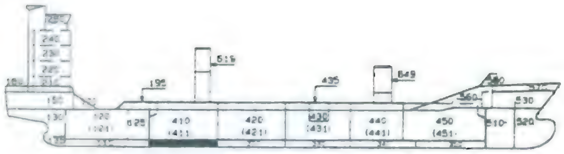
An oil tank and a drinking water tank must be separated by an empty space, a so-called **cofferdam**. The wing tanks are separated by watertight web frames. The shell stiffeners in the double bottom and the wing tanks usually run in a longitudinal direction.
When a ship has a length of approximately 60 meters or less, for instance a tugboat or fishing vessel, the frames run in a transverse direction. Sometimes a combination of the two systems is used, when the double bottom and the main deck are longitudinally framed and the side ones are transversally framed.
The double bottom is covered by the tank top and thereby separated from the hold.
Several piping systems run through the double bottom, such as piping for fuel, bilge or ballast water systems.
Container ships need reinforcements in the double bottom at the corners of the containers.

Floor plates in the double bottom can be divided into:
- water- or oil-tight floors (non-tight plate floors)
- floors, that can be reduced in weight by manholes (also for access)
- floors made of profiles and brackets (open floors)

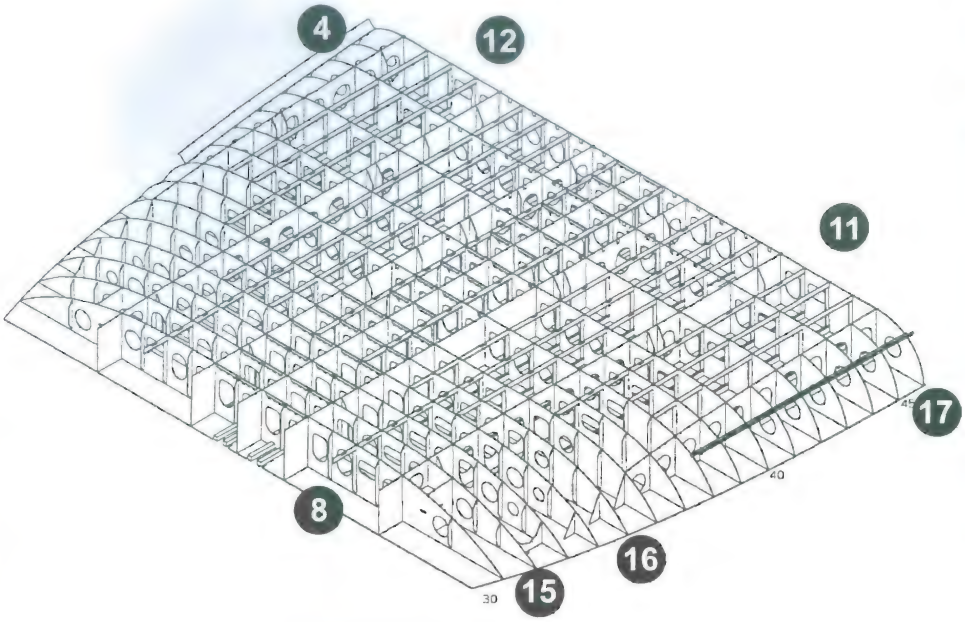
Vents and openings are installed for the filling and emptying of the tanks. Every double bottom tank must be fitted with a sounding pipe, normally aft (with a small doubling underneath) and a vent pipe forward and aft in each tank. Tank contents are often measured by special measuring devices, with a display in the cargo control room. This can be a float, connected to a counter, sending a signal to the computer in the control room, a bubble-pipe system working on air pressure or even a tank-radar.
The double bottom is accessible by bolted manhole covers in the tank top; every tank must have a possibility for entrance. Fuel tanks often have a system for heating fuel (depending on the type of oil). Most ships burn heavy fuel, and the viscosity depends on the temperature. The fuel tanks therefore are usually provided with **heating coils**, through which hot water, steam or thermal oil circulates.

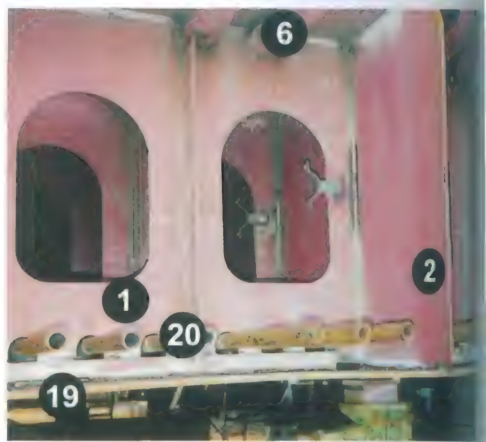


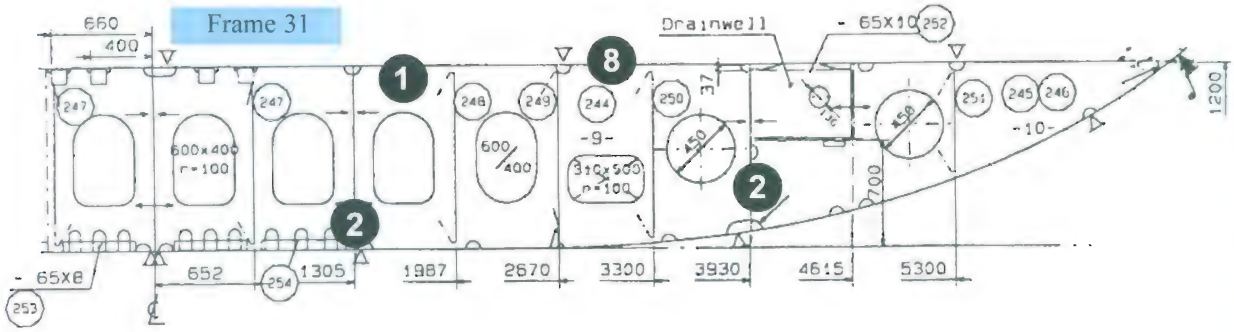
1. Center keel (watertight)
2. Side girder
3. Bottom longitudinal
4. Watertight or oil tight floor (plate floor)
5. Full floor (plate floor)
6. Center keel bracket (docking bracket)
7. Ballast line
8. Bilge line
9. End of ballast line, with suction
10. Side shell longitudinal
11. Watertight or oil tight bulk heads
12. Web frame
13. Hatch coaming
14. Coaming bracket
15. Main deck (gangway)
16. Ballast or fuel tank
17. Top plate of engine foundation
18. Poop deck
19. Ventilation trunk of cargo hold
20. Deck house front

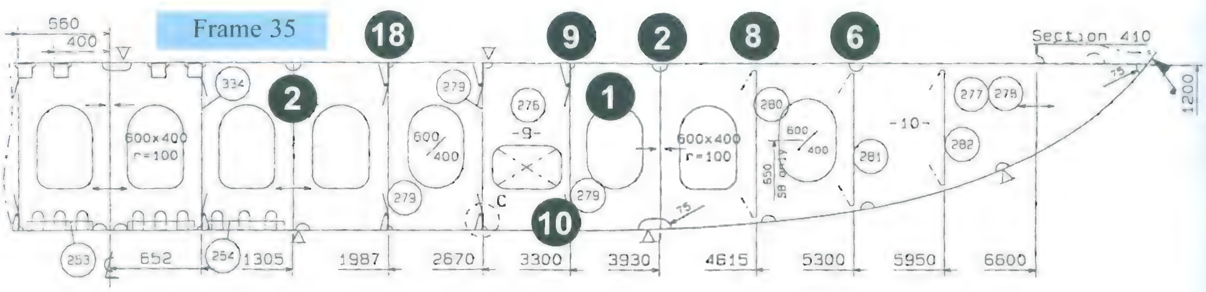


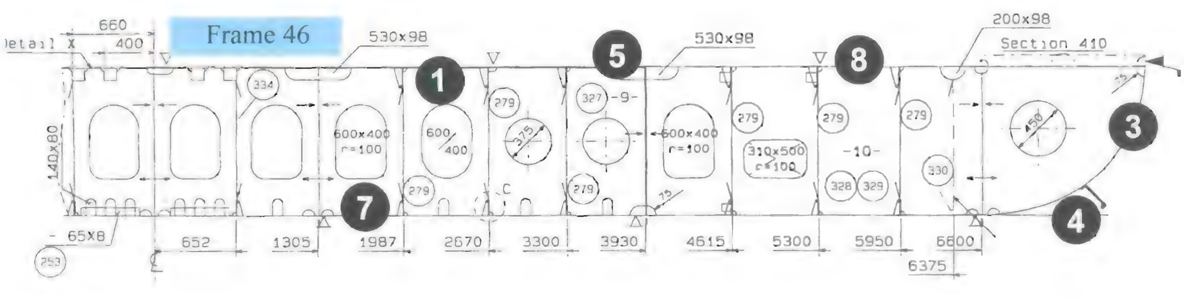
Location of the section in the ship



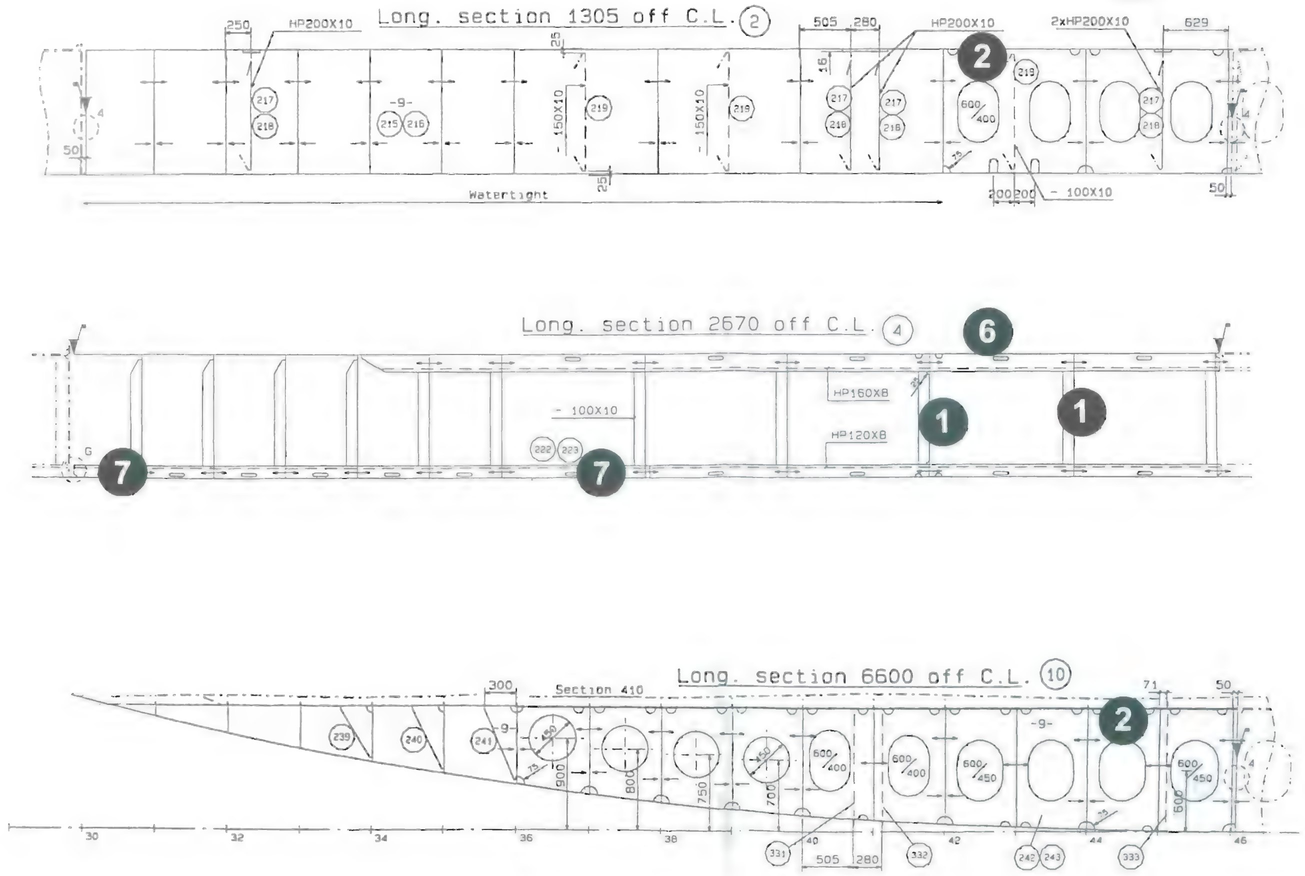








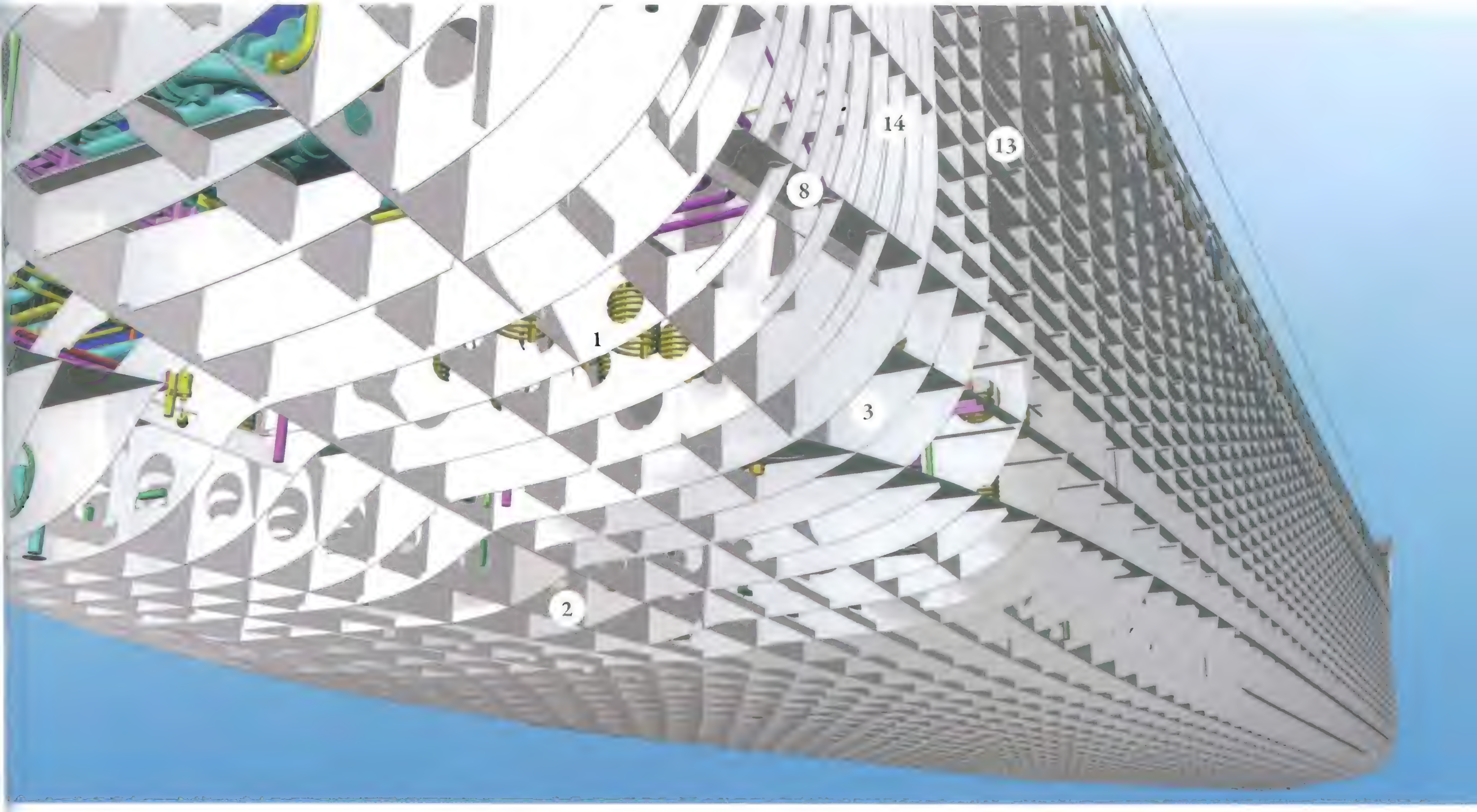
Transverse cross-section



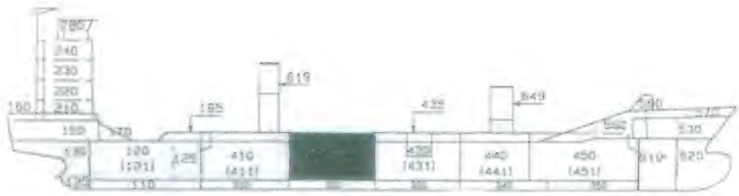
Longitudinal cross-section

Explanation of the images on these two pages:

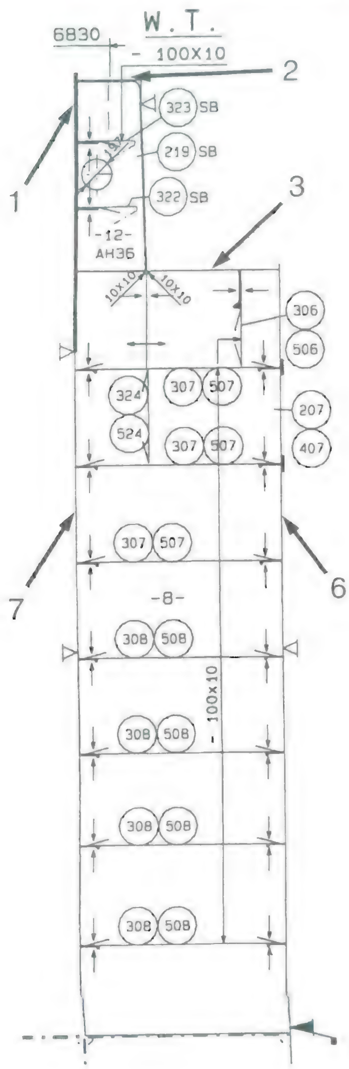
1. Full floor (plate floor)
2. Side girder
3. Bilge bracket
4. Bilge keel
5. Recess container pot
6. Air holes
7. Drain holes
8. Tank top
9. Tank top longitudinals
10. Bottom longitudinal
11. Port side
12. Starboard side
13. Longitudinal framing system
14. Transverse framing system
15. Floor on frame 31
16. Floor on frame 35
17. Floor on frame 46
18. Longitudinal slots
19. Bottom shell
20. Heating coils
21. Synthetic pipe for ballast tank

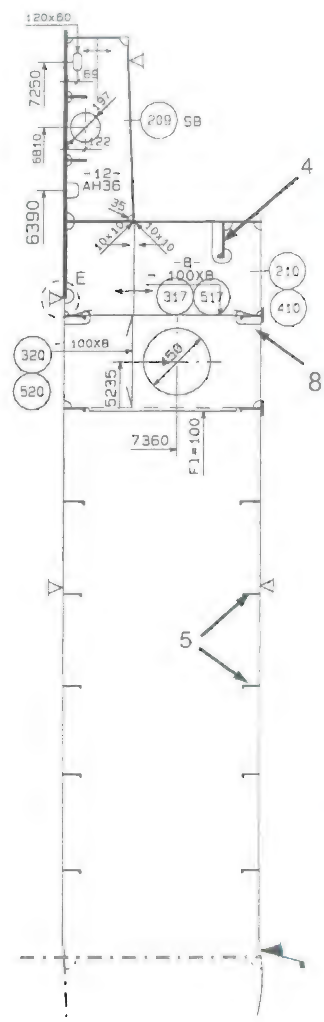


1. Hatch coaming plate
2. Toprail
3. Gangway
4. Deck longitudinal
5. Side shell longitudinal
6. Shell plating
7. Longitudinal bulkhead, tank side
8. Scallop

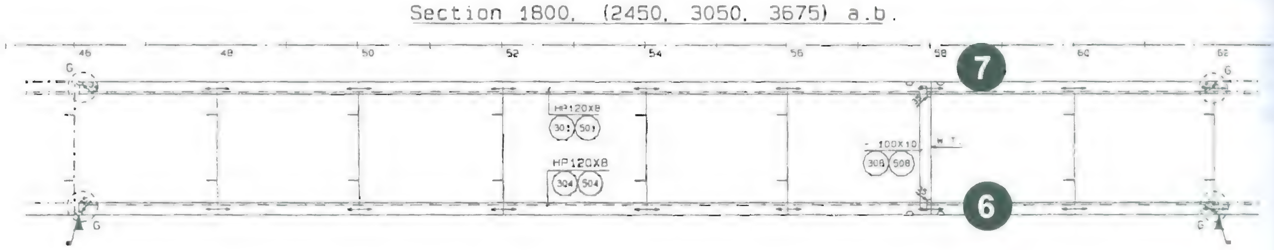


Location of the section in the ship

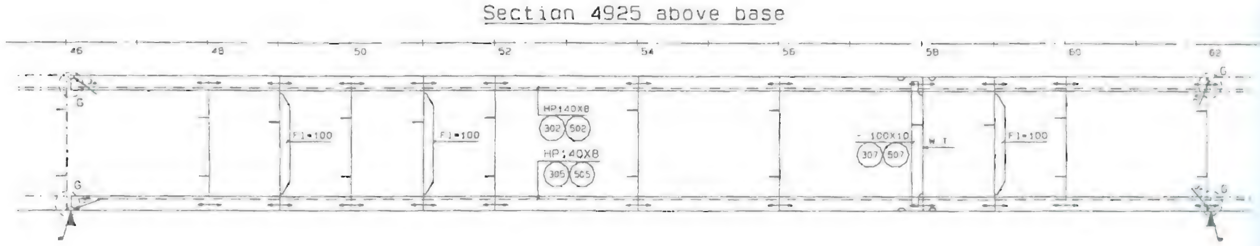


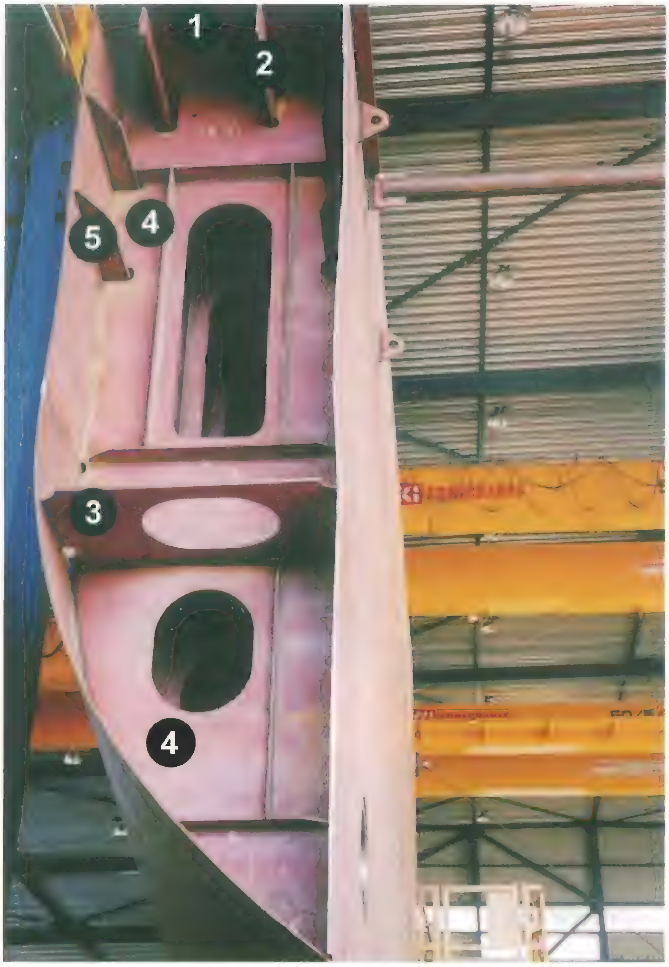


Section 1800, (2450, 3050, 3675) a.b.



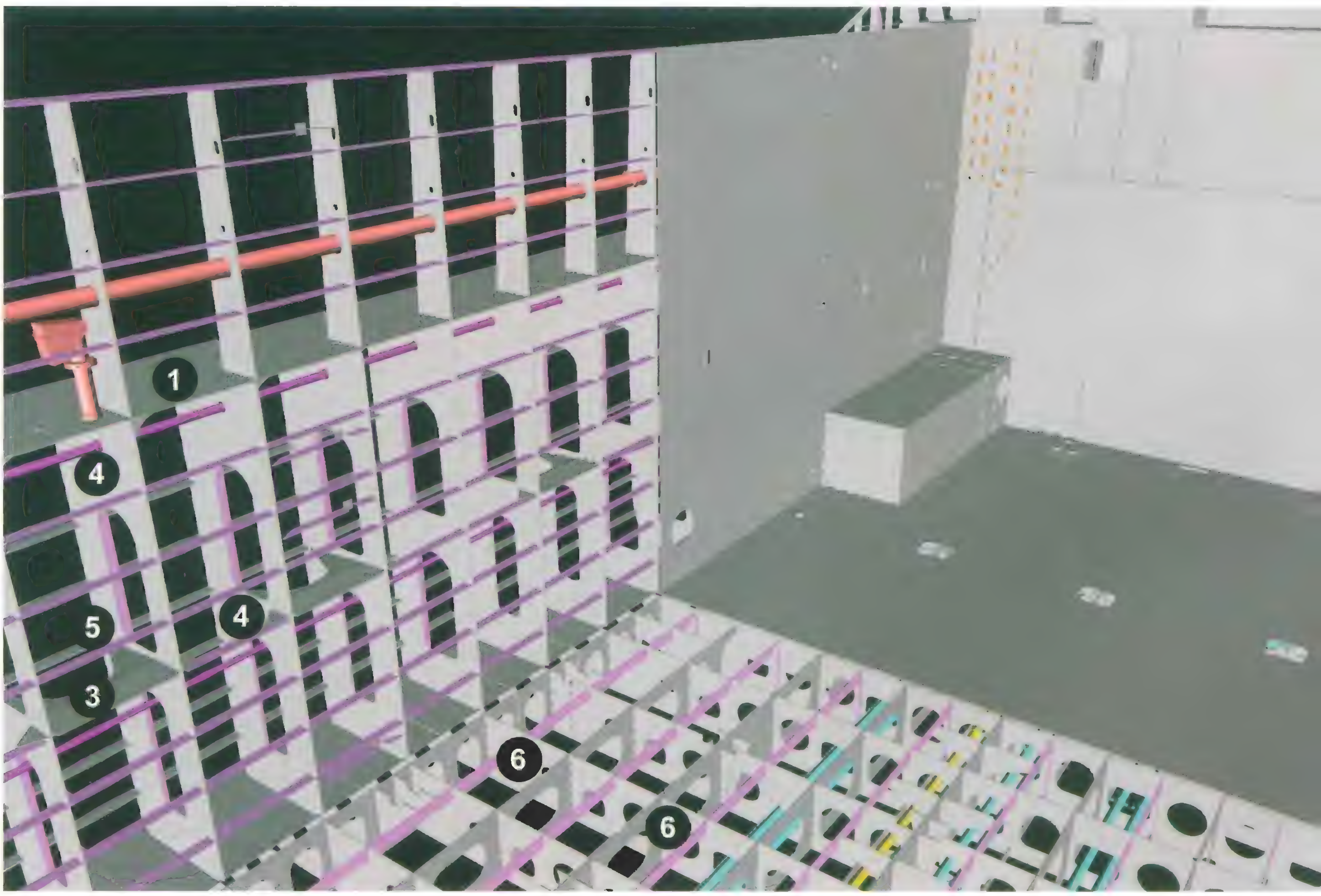
Section 4925 above base



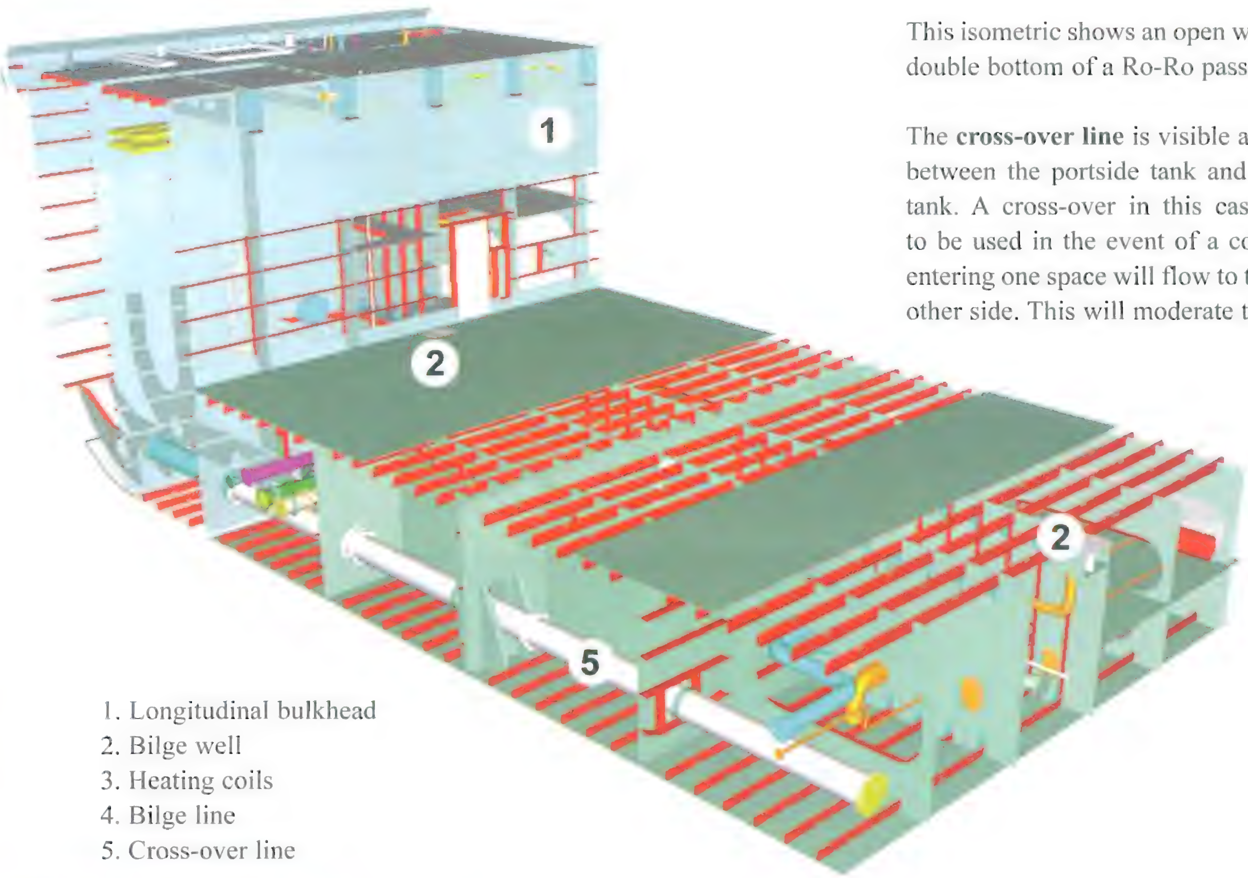


A worker leaves a side tank in a multipurpose ship, via a manhole

1. Main deck
2. Deck longitudinal supporting the tip of the coaming bracket
3. Stringer
4. Web frame
5. Side shell longitudinal
6. Full floor (plate floor)



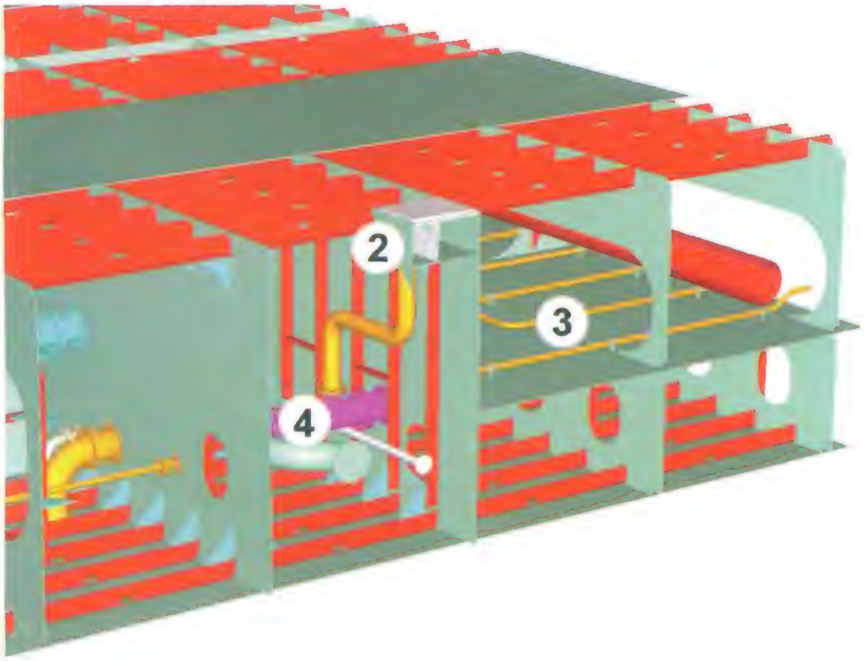
Location of the section in the ship



This isometric shows an open wing tank and a double bottom of a Ro-Ro passenger ferry.

The **cross-over line** is visible as an open line between the portside tank and the starboard tank. A cross-over in this case is designed to be used in the event of a collision. Water entering one space will flow to the tank on the other side. This will moderate the list.

1. Longitudinal bulkhead
2. Bilge well
3. Heating coils
4. Bilge line
5. Cross-over line



The system can reduce damage stability requirements. The majority of ferries and passenger liners have such a cross-over system.

The drawings show:

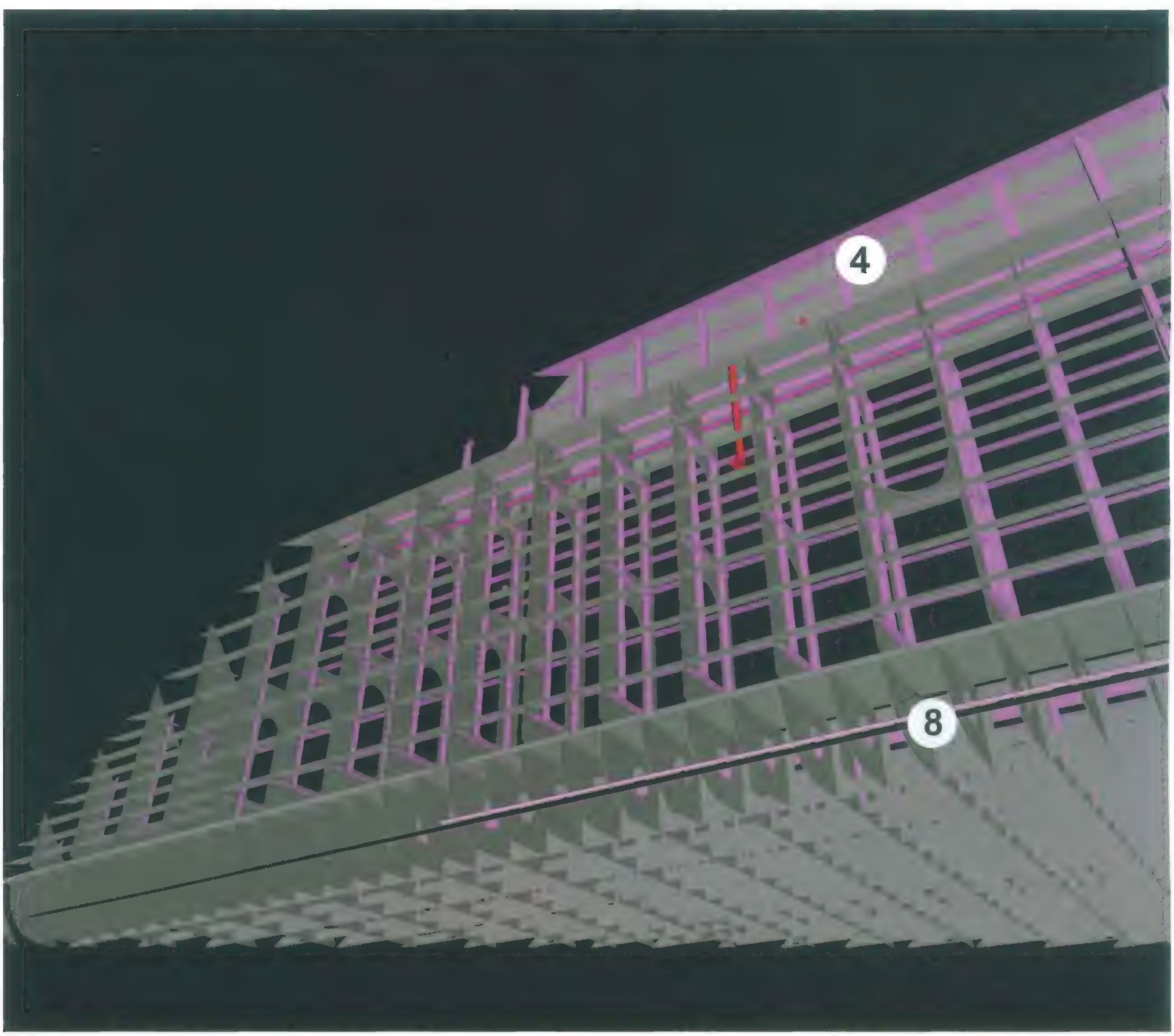
- Bilge wells - fluid present in the compartment will flow to the bilge well and can then be removed by the bilge pumping arrangement.
- Heating coils - these are in the heavy oil tank. If the oil is too viscous to be pumped, it will be heated up to a 'safe viscous' temperature.

Side view

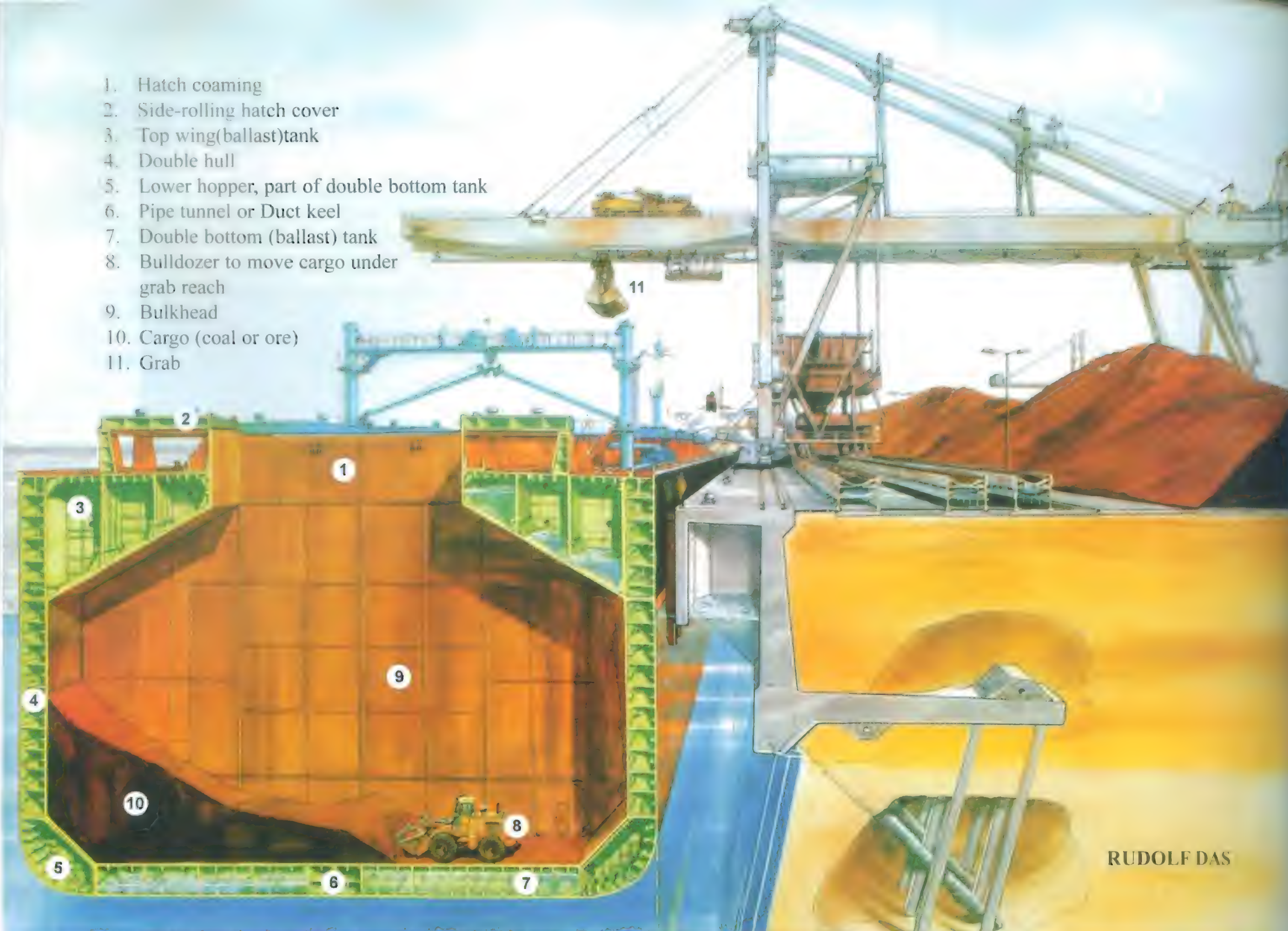
Explanation of these three images:

1. Draft mark
2. Plimsoll mark
3. Deck line
4. Bulwark
5. Container strut
6. Bilge strake, approximately 10 mm thick
7. Backing bar
8. Bilge keel, approximately 220×15 mm (for this particular ship) The bilge keel is welded onto a flat bar. When damaged, the bilge keel will break off, with the strip remaining attached to the shell. Without a backing strip, a crack in the bilge keel could continue into the bilge strake, which is very dangerous!

Bilge keel

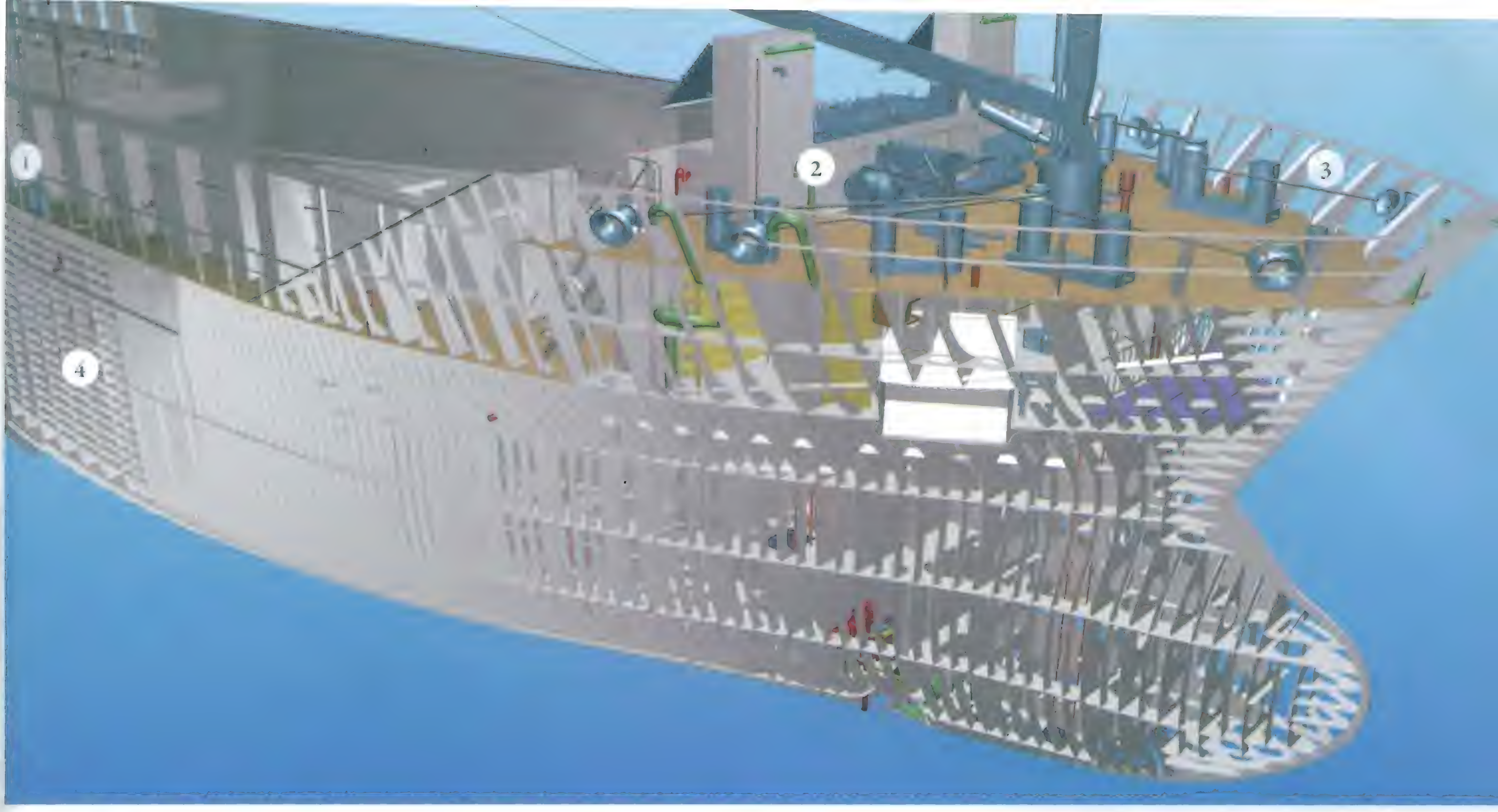


Cross section of the midship



Bulk carrier, capesize, alongside discharge berth.

Huge heeps iron-ore and coal stored ashore in the Port of Rotterdam waiting for further transport



5 Bow

The bow is the part of the ship between the stem and the collision or fore peak bulkhead, and the adjacent part aft of the fore peak, to the parallel mid body.

The space forward of the collision bulkhead and below the main deck, is the **fore peak**. The fore peak tank is the lowest space in the bow and is often divided in a lower and an upper fore peak tank. The fore peak tank is usually used as a ballast tank. If the ship is not loaded this is often filled with water to increase the draft and to reduce the trim by the stern.

Usually there is a wash-bulkhead at the center line in the peak tanks. This prevents **sloshing** (the fast movement of water from port to starboard) when a tank is partially filled. It also improves the rolling-behavior of the ship. Directly behind the fore peak there can be another tank (deep tank) that extends from starboard to port and from the bottom to the deck; used for ballast or fuel.

In the top of the fore peak, right below the anchor windlass there are **chain lockers** for the storage of the anchor chains. Above the weather deck in the bow there is often a **forecastle**, a superstructure from bow to above the collision bulkhead. Sometimes it is extended further aft, to even aft of number one hatch. The forecastle is protected against rough seas by a **bulwark**. On the forecastle are the windlass and other mooring equipment. The fore mast is usually located at the rear part of the forecastle deck.

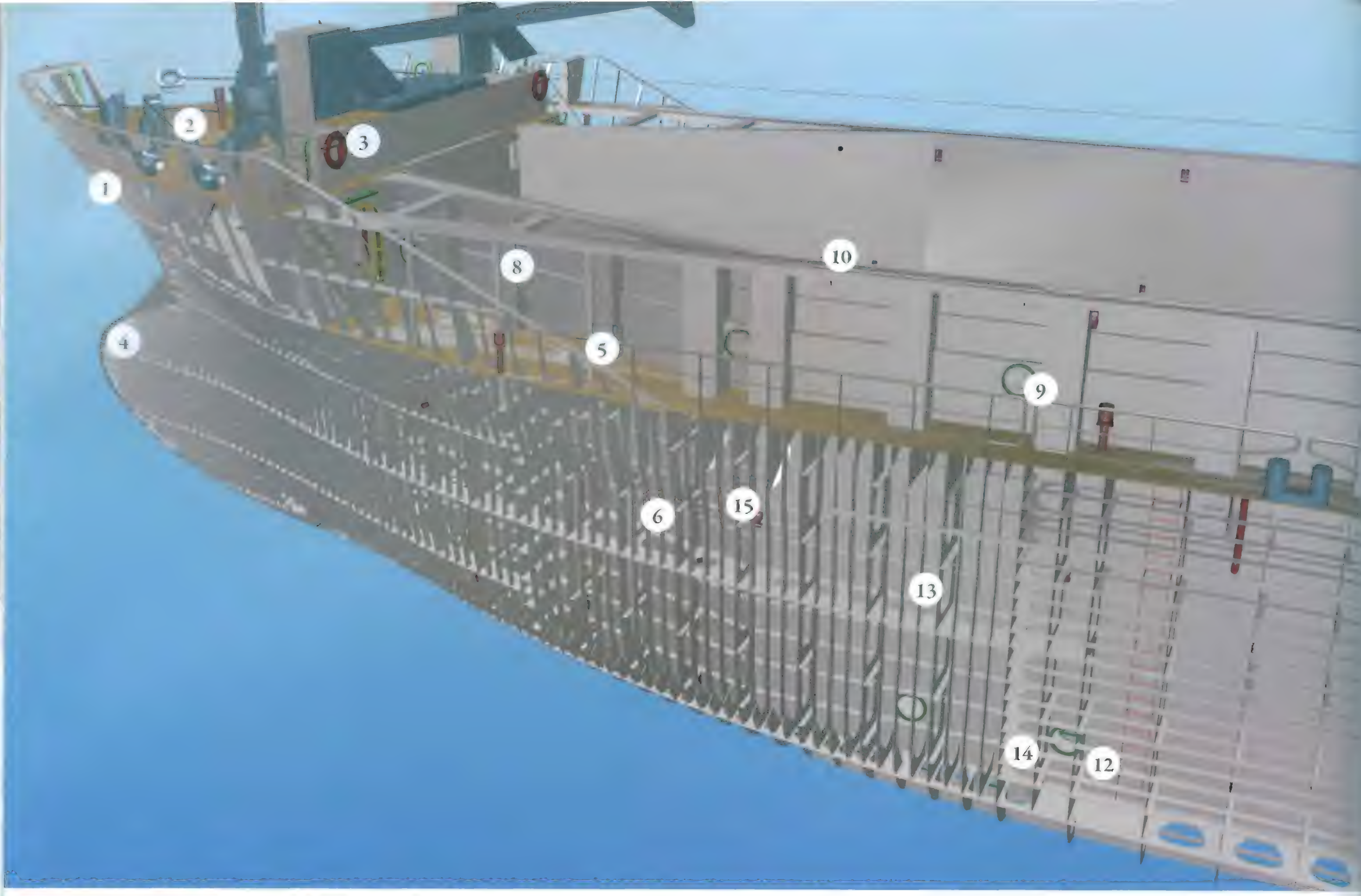
The forecastle can be divided into:
- stores and workshops for ship maintenance:
  - tools for work on deck (bosun's store, carpenter's store)
  - storage for paint (with fixed fire-fighting equipment)
  - storage for ropes.
- Storage for cargo-handling equipment like:
  - twist locks, (container lashing equipment)
  - slings, shackles,
  - airbags.

These items are usually stored in racks made for this purpose. If necessary, these racks can be lifted up by the ship's crane or the crane of the hatch cradle.

Container-lashing gear is often stored in boxes along the hatch coaming.

Explanation of the image:
1. Hatch coaming
2. Breakwater
3. Bulwark stanchions
4. Transition from longitudinal to transverse framing system

The fore part is being attached to the ship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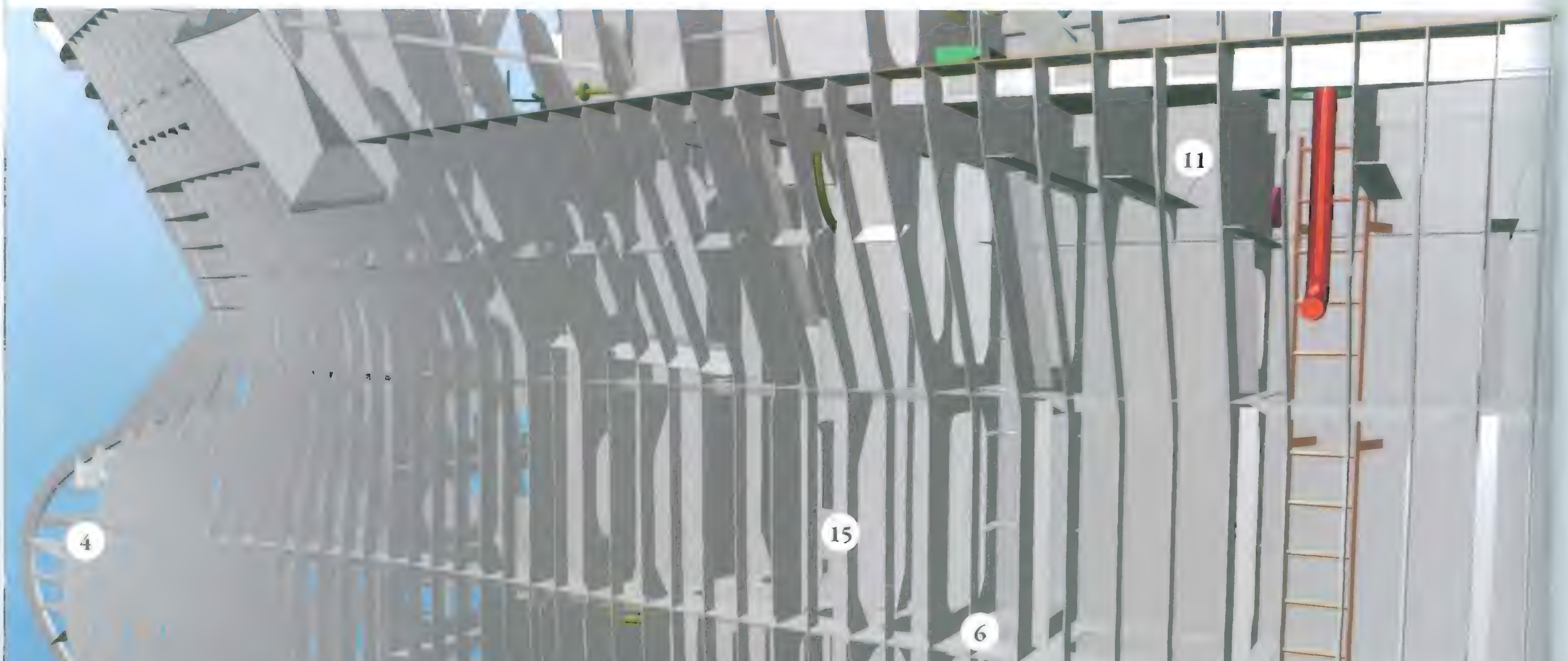
11
4
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6
7

Explanation of the images on the left page:

1. Bow
2. Forecastle deck
3. Break water
4. Bulbous bow
5. Main deck
6. Stringer
7. Bow thruster room
8. Hatch coaming with brackets
9. De-aerating pipes
10. Top rail
11. Vent of the wing tank
12. Access / lightening opening
13. Transition of transverse to longitudinal framing system
14. Tank top
15. Web frame

The bow is subject to extra ordinarily large forces, acceleration and stresses caused by:

a. the pitching of the ship (pitching stresses).
b. the fore peak moving in and out of the water (panting stresses).
c. maintaining speed in heavy weather
d. ice

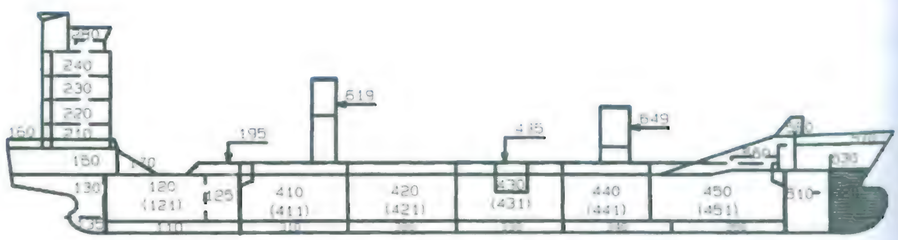
Items stored in the fore peak spaces need to be properly **seafastened**, in connection with the acceleration forces.
To compensate for the forces mentioned, the forward part of a ship needs additional reinforcements that sometimes extend to midships.
A bulbous bow can be added to reduce wave-resistance. The bow wave and fore-shoulder-wave cause a resistance that has a negative influence on the speed of the ship. The added bulb creates a wave which interferes with the bow and shoulder waves ideally eliminating them, thereby improving the wave resistance of the ship, however, only for the draft the bulb has been designed for.
The design of the bulb varies from a long knife-type form, to a ball form.
The ideal situation is one where the ship cuts through the waves, generating **no waves** itself. Every wave created by the ship is energy wasted.

The bulb is most effective at a certain draft, for loaded or ballast condition. It could well be that in the case of an adverse situation a bulb produces more resistance (see chapter on propulsion).

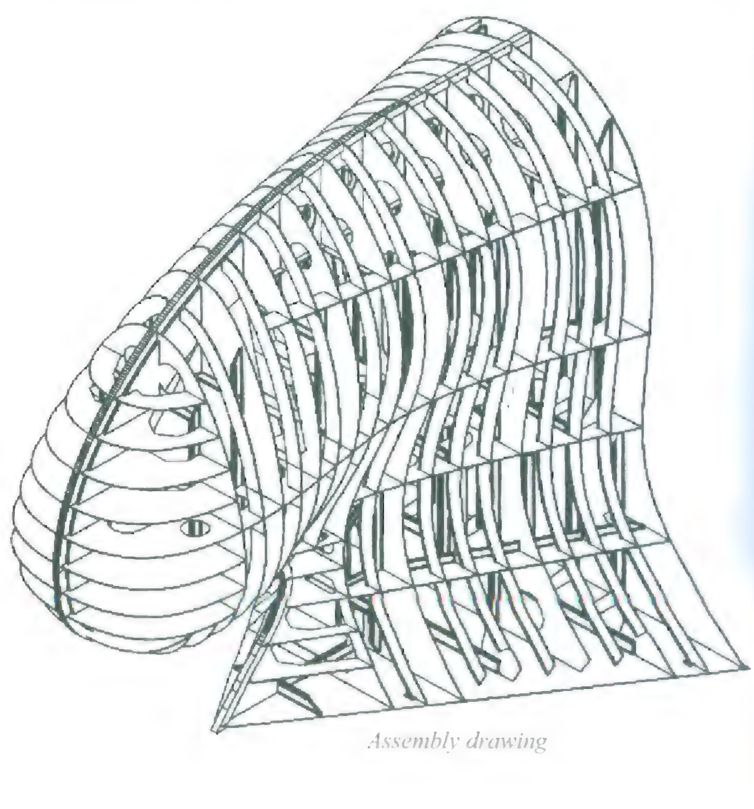
Stiffening	Location	Objective
Reduced frame spacing	Foreship: 700 mm	a.c.
Reduced frame spacing	Fore peak: 600 mm	a
Smaller spacing internals general (floors and side girders)	Double bottom fwd	a
Panting area (stringers, horizontal beams)	Fore peak	a.b.
Intermediate frames	Fore peak	a.b.
Web frames, side girders	Fore peak	c.
Increased shell thickness	Draft	b.

A well-designed bulbous bow

1. Bulbous bow
2. Breast hook
3. Floor
4. Floor stiffener
5. Access / lightening opening
6. Stringer or flat
7. Center keel in bulb
8. Stem bar
9. Transition of flat to shell stringer
10. Shell frame (HP)
11. Hawse pipe
12. Anchor pocket
13. Chain locker
14. Watertight bulkhead (collision bulkhead)
15. Ladder to the forecastle deck
16. Weather deck (main)
17. Emergency fire pump / bilge pump
18. Bilge line in bow-thruster room
19. Fore peak (water ballast)
20. Bow-thruster tunnel
21. Floor slab in bow-thruster room
22. Deep tank (water ballast)
23. Floors
24. Wash bulkhead at the center line of the ship



Location of the section in the ship



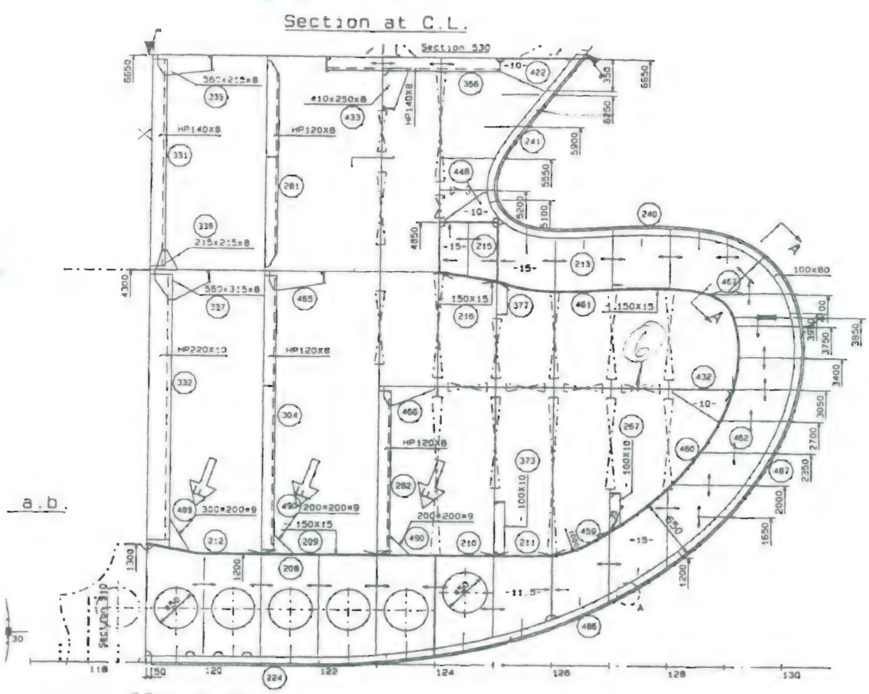
Assembly drawing

Fitting of the shell plating

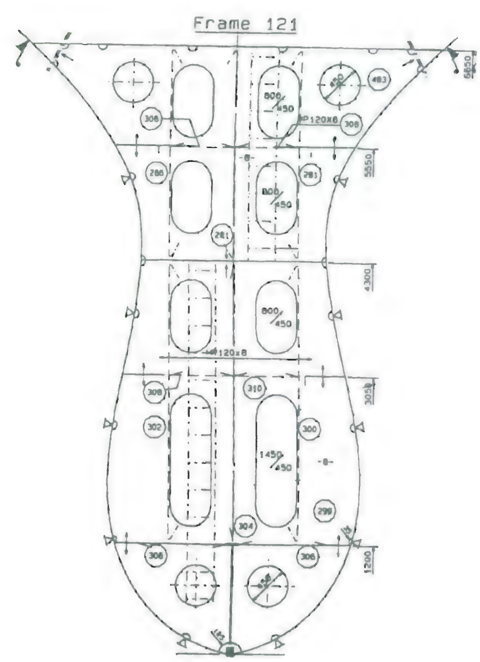
Fore peak, ready to be installed

Frame 121

Stringer 4300

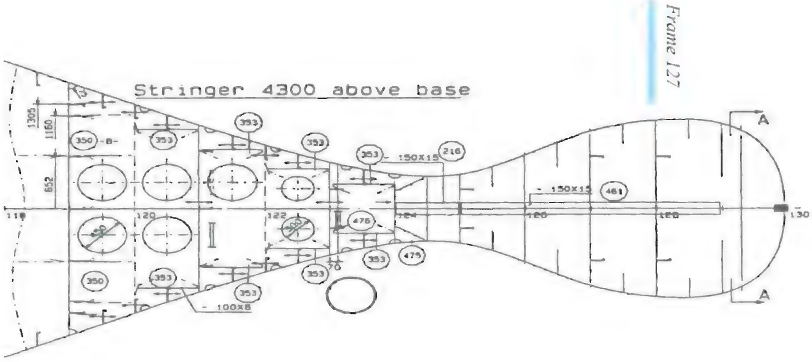


Longitudinal cross-section of the fore peak

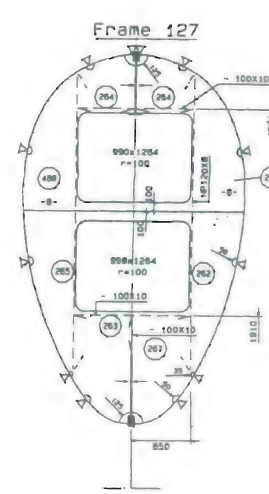


Transverse cross-section at frame 121

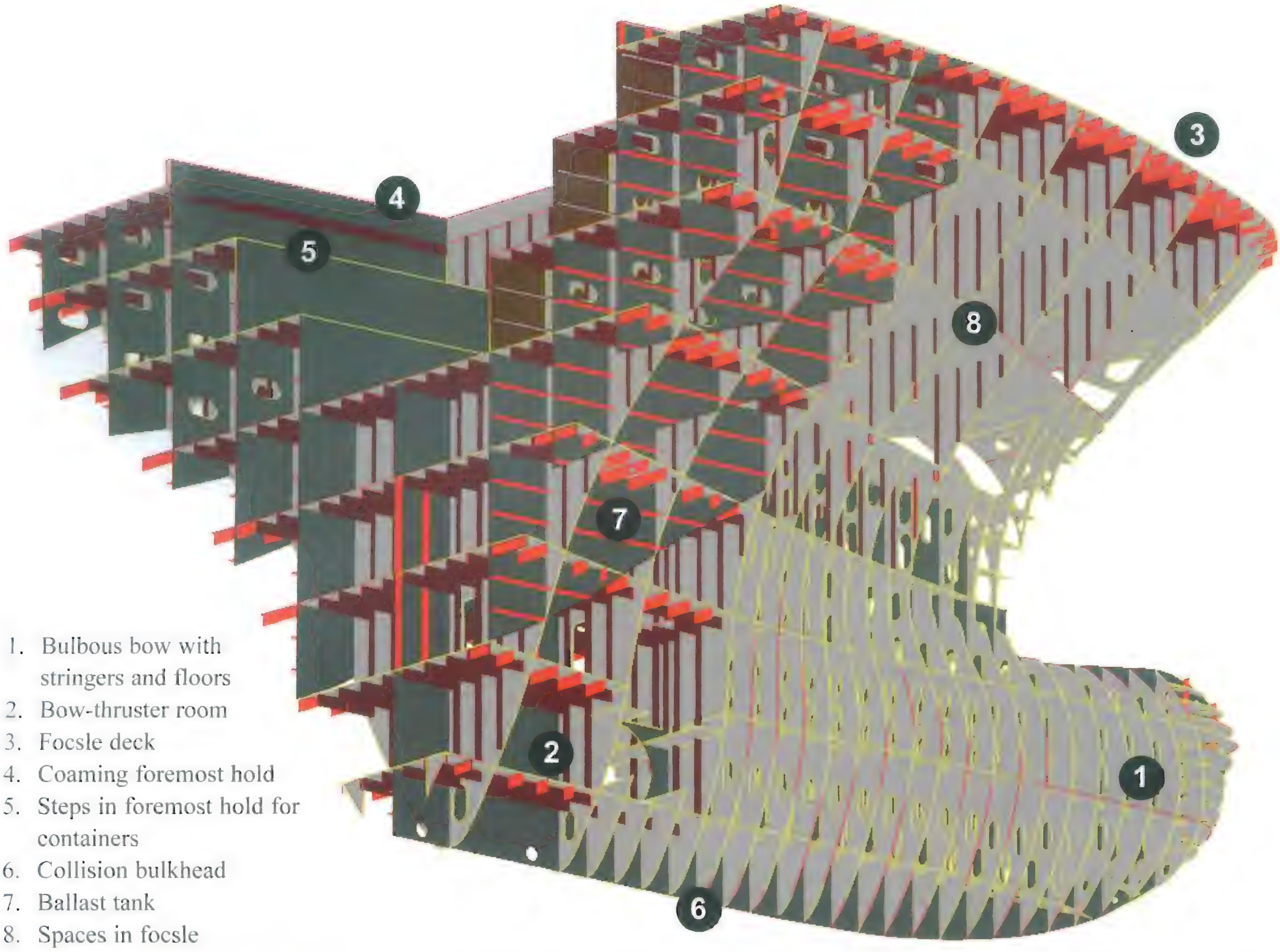
Frame 127



Horizontal cross-section at 4.30 m above the baseline



Transverse cross-section at frame 127



1. Bulbous bow with stringers and floors
2. Bow-thruster room
3. Focsle deck
4. Coaming foremost hold
5. Steps in foremost hold for containers
6. Collision bulkhead
7. Ballast tank
8. Spaces in focsle

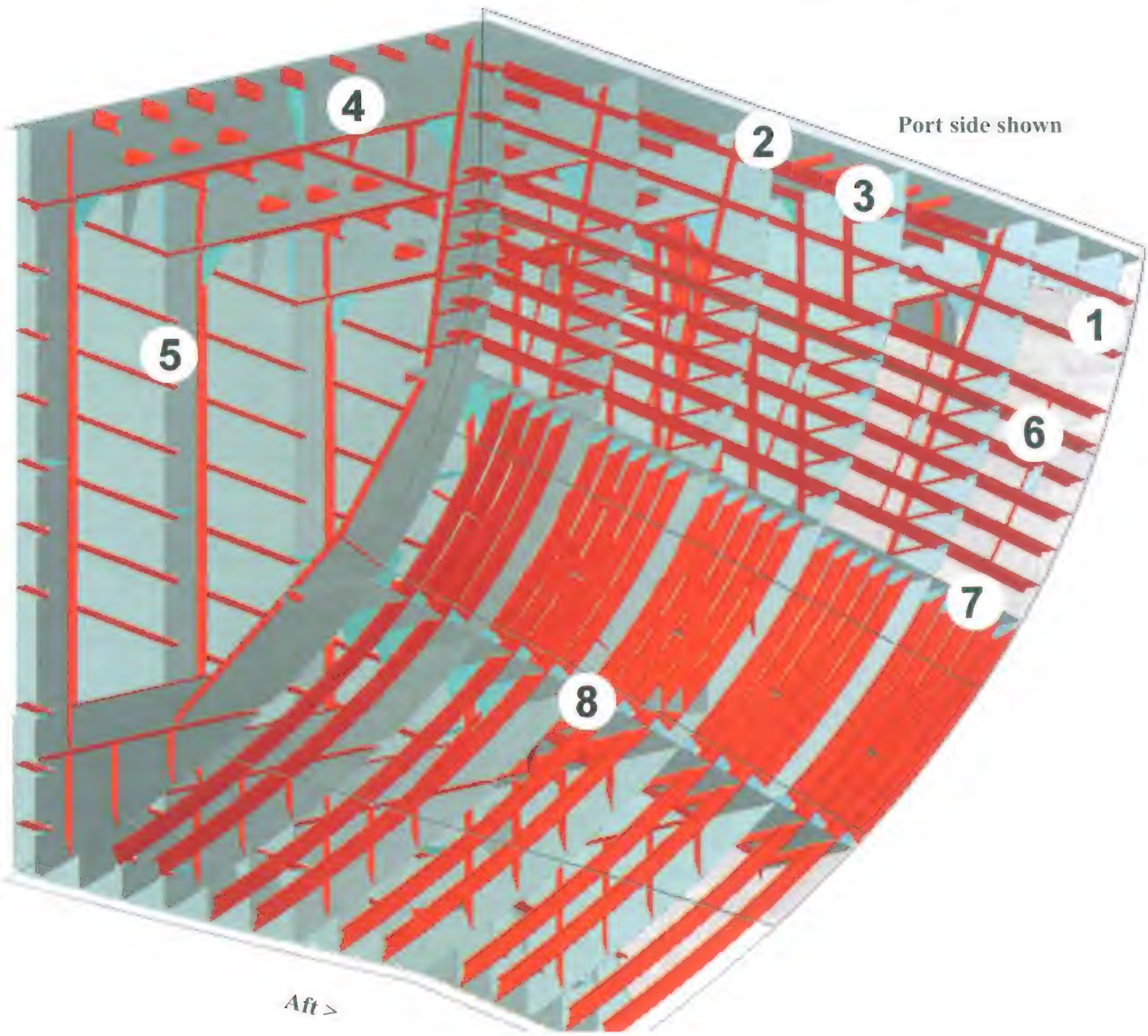
Similar container ship such as one above

Location of the section in the ship

Below, detailed drawing of the ship above gives a clear picture of the various framing systems. Note that the web frames are never isolated but are always part of a ring frame. For every three frames there is a web frame. The stiffening under the main deck runs in longitudinal direction.

Directly underneath this is the ice belt; in this section there is an extra frame for every frame. The ice strake can run all the way from forward to the place where the ship is at its widest.

1. The aft direction
2. Main deck
3. Deck beams
4. Deck longitudinal
5. Longitudinal bulkhead with longitudinal framing
6. Longitudinals
7. Transverse framing for ice strengthening
8. Transverse frame



6. Accommodation

6.1 Introduction

In the past, the accommodation of the crew was not the most important aspect in the design phase. The reason for this was the large number of men in the crew compared to the present day. Thirty years ago a crew of forty manned a vessel that today may have a crew of twelve. Due to the added workload of today's crew, there is growing pressure to improve facilities for personnel. When the size of the ship permits, cabins are for one person only, have separated day and bedroom, are well equipped and have their own toilet and shower. As a result of smaller crews and shorter lay days, the importance of recreational and leisure facilities has grown (a gym, satellite telephone connection from all crew cabins, central antenna system, etc.).

The height of the accommodation is important for the view from the bridge. Large ships, with the accommodation aft, and, when in ballast with a considerable trim, and thus a long dead sector, need a higher accommodation than ships with the deck house forward.

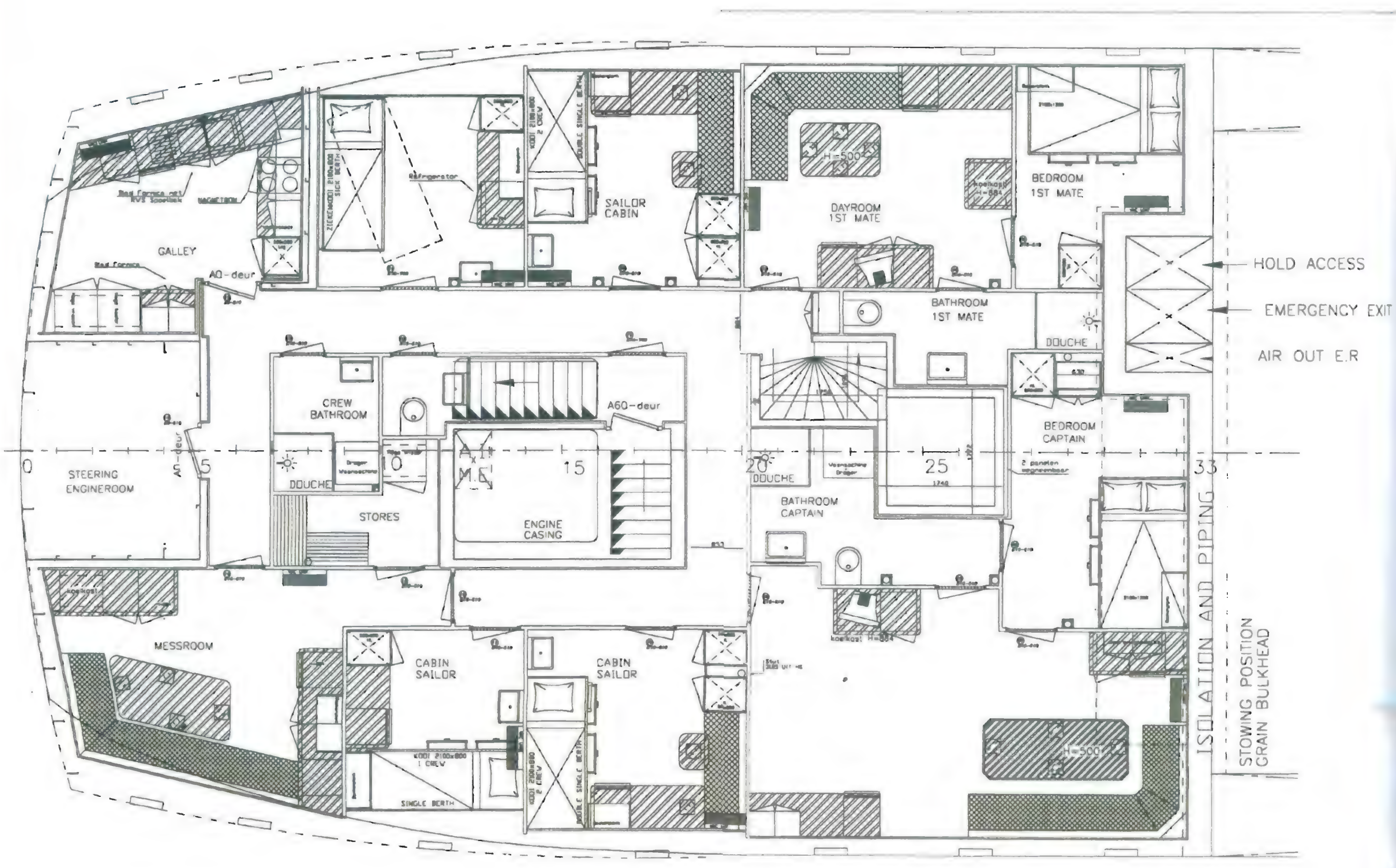
6.2 Safety

In particular safety-equipment demands focus on the prevention of fire. These demands are stated in SOLAS resolution, chapter II-2 "Construction - Fire protection, fire detection and fire extinction". The chapter consists of the following parts:

Part A: General
Part B: Fire safety measures for passenger ships
Part C: Fire safety measures for cargo ships
Part D: Fire safety measures for tankers.

1. Sufficient mess room accommodation shall be provided in all ships
2. In ships of less than 1,000 tons separate mess room accommodation shall be provided for:
   (a) master and officers
   (b) petty officers and other ratings
3. In ships of 1,000 tons and over, separate mess room accommodation shall be provided for -
   (a) master and officers
   (b) deck department petty officers and other ratings
   (c) engine department petty officers and other ratings
4. Adequate mess room accommodation shall be provided for the catering department, either by the provision of a separate mess room or by giving them the right to use the mess rooms assigned to other groups.

Example of International Labour Organisation (ILO) extraction.



Main deck plan of the accommodation on a coastal trade liner

d. Lighting and Daylight

High standards are set for lighting in work and living spaces. Lighting armatures should be able to resist the vibrations on a ship and should be easily accessible for maintenance.

Windows (port holes) in cabins and other spaces should have the dimensions and placement that one is able to look outside both sitting down and standing up. There are also certain requirements for port holes, like the design pressure and the position on board (e.g. not below the freeboard deck).

6.4 Methods of Insulation

Insulation material has to be installed against inside and outside temperature differences, heat in case of fire and noise

All accommodation decks and bulkheads which are in contact with the outside or hot locations in the ship, such as the engine room need to be insulated against heat and cold.

a. Rock or Glass wool patches

Walls

Batts of rock wool or glass wool are attached to welded pins that have already been placed on the steel plating.

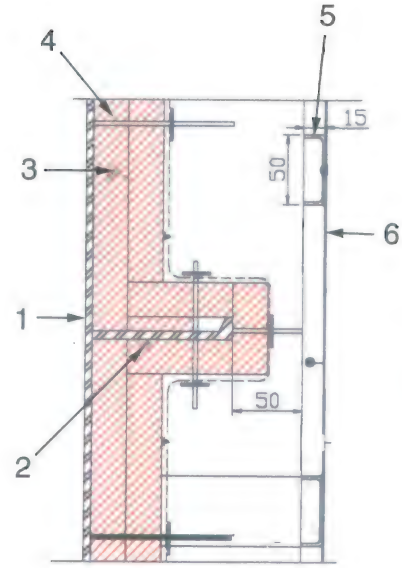
Thickness depends on the difference in temperature inside and out. The drawing shows an example of fire protection and thermal insulation. The panels of the accommodation are free of contact with the insulation to prevent the transfer of vibrations.

The panels are attached to U-profiles which, in turn, are attached to the insulating floor.

– **Flooring**

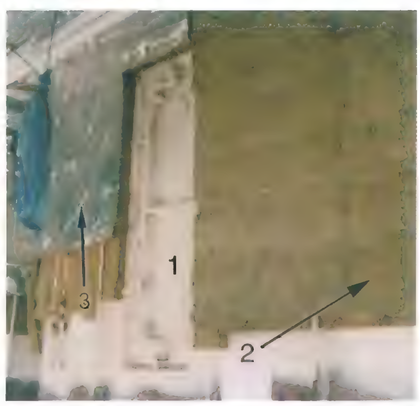
To minimize disturbing sounds and reduce the chances of fire, the floors (especially if they are directly above the engine room) are built as sprung floors.

These floors can consist of multiple layers of steel wool with a large density (e.g. baffles) placed on the steel deck, covered by a hard ground slab.



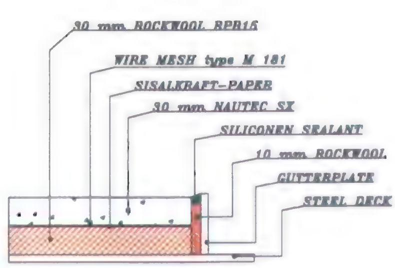
Fire and thermal insulation

1. Steel plate (outside of accommodation or inside boundary)
2. HP-profile
3. Glass wool
4. Welding stud
5. U-profile
6. Accommodation panel (a galvanized steel plate of 1 mm thickness)



Part of accommodation insulated by glass wool on welding pins

1. Weather tight door
2. Insulation on welding studs, covered by wire mesh
3. Moisture-proof aluminum foil



Sprung floor

Bridge

Port hole

Galley

b. Sprayed Polyurethane Insulation (or other foam)

This form of insulation is sprayed as a liquid on the bulkhead, expanding into foam instantly. Spray insulation can be used for thermal insulation, sound absorption and fire resistance (melting temperature up to 750 °C).

6.5 Communication

Each cabin has to be equipped with a telephone and terminal for a central antenna for radio and TV. For operational and safety reasons it is necessary that each member of the crew can be summoned or warned at any time and place.

Applying insulation

6.6 Maintenance

Cleaning and maintenance of the accommodation is a necessary for both hygiene and appearance.
In general, the arrangement of the accommodation should be aimed at easy and efficient cleaning and maintenance. Things that have to be taken into account are:
- prevention of dirt transfer from work to living space
- proper choice of materials (clean and easy to maintain)

In the design phase it is important to:
- include enclosed compartments where dirty overalls can be taken off and hands can be washed
- a cleaning-gear locker on every deck in the accommodation.

6.7 Overview of the different spaces

Bridge
Always on the highest deck. This is where all means of communication and navigation are situated. Connections need to be provided with engine room, steering-gear room, all cabins, etc. Some ships even have the engine-control panel in the wheelhouse.

From this point, the ballast system, which is located in the engine room can be accessed.

Lockers in the accommodation

Duty-deck
On large ships, the lowest deck in the accommodation, often one deck above the main deck, is a working deck where you can find the cargo office, captain's office, meeting room, galley and mess rooms.
Apart from the bridge every space above this deck is private.
On the duty deck combinations of space usage depends very much on the size of the ship.

Captain's office
For the captain a (small), separate office.

Cargo office
This is the room where the captain or chief mate deals with agent, cargo-receivers, customs, ship chandler, suppliers, etc.

Meeting room
A place where daily work meetings are held.

Cargo control room
On board tankers and bulk carriers, the loading and discharging, ballasting and de-ballasting is controlled from the cargo control room. Smaller ships can have a control panel on the bridge.

Galley
The food is prepared here. It is situated near the mess room to keep the walking distance as small as possible.

Mess
Dining room for officers and crew.

Duty-mess
A small room with table, chairs and a cabinet where crew can eat in dirty clothes, in case there is too much work on deck or in the engine room.

Next highest deck:

Lounge
This is the focal point of social activities outside working hours.

Laundry
A space located centrally, with at least a washing machine and dryer.

Hospital
The arrangement of this space is subject to legal requirements. Furthermore, it has to have easy access for a stretcher.

Cabins
These are being increasingly standardized. For example, the captain, chief engineer, chief officer and lower officers all have a cabin of similar size. Additionally, there may be one or two other types of cabins.
Nowadays, cabins can be finished completely at the building place (prefab). After placement on the ship, only terminals for electricity, water, ventilation, heating, etc. have to be installed and connected.

Owner's cabin
Usually on the same deck as the captain's cabin, chief engineer's cabin, an owner's cabin is located, of a quality similar to that of the captain's cabin. This is a passenger cabin, for office staff, a pilot, superintendent or other person not belonging to the crew.
For occasional workers, there is usually a cabin with 4 or 6 bunks, lower in the ship, eventually combined with the cabin for the Suez mooring gang, needed when the ship has to do a Suez Canal transit.

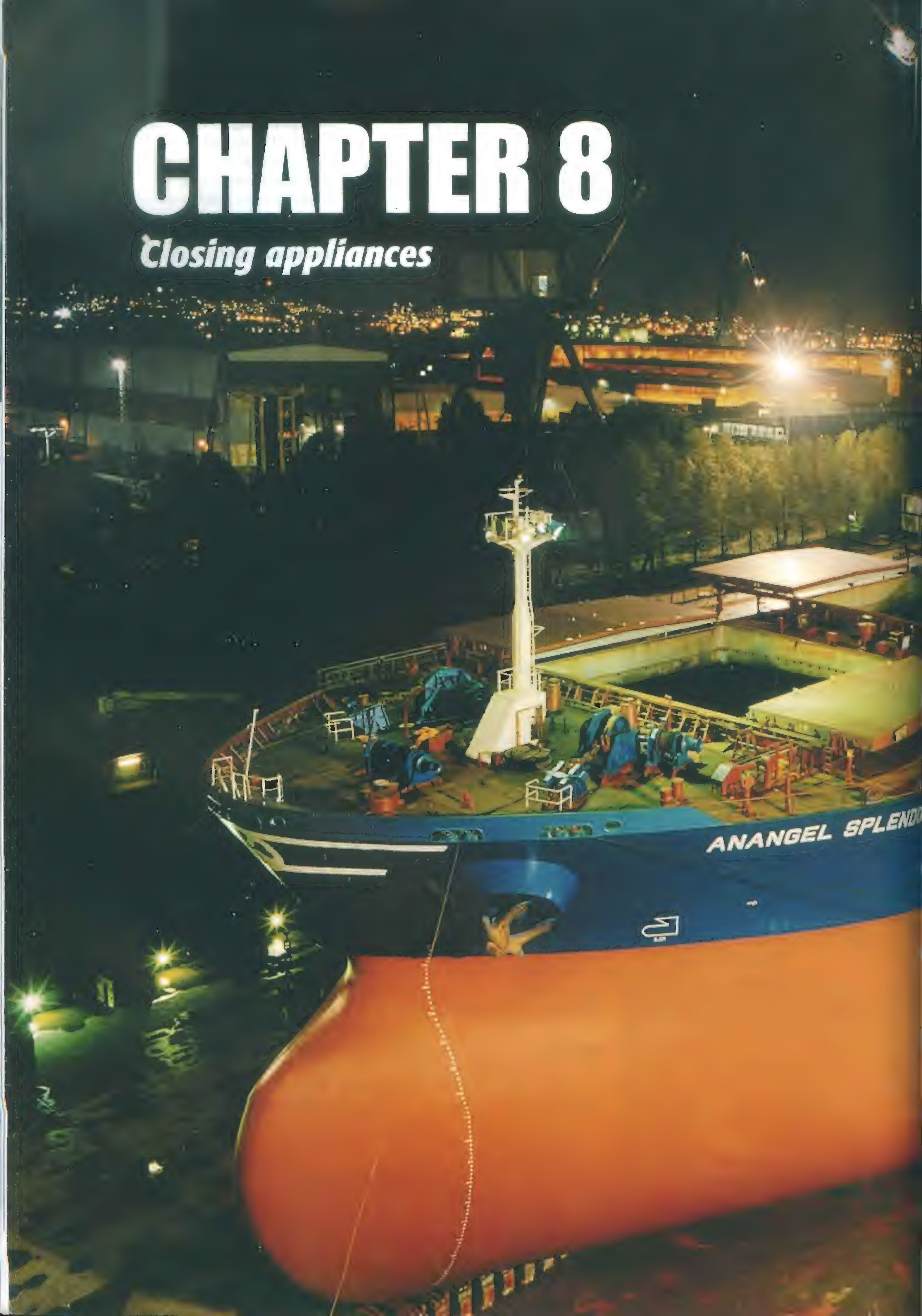
Stores
Storerooms contain:
- provisions and cold stores near the galley
- bonded store, also near the galley
- luggage lockers on all cabin decks
- engine spare parts and tools near or in the engine room
- paint locker, forward or aft, isolated from the accommodation, with entrance from outside only
- garbage locker near incinerator and galley, only accessible from outside

The main deck, below the accommodation spaces, is used as the work deck or for stores, engine room stores, etc. depending on the ship's size.

Often a CO_2 room is located here.

CHAPTER 8

Closing appliances



1. Introduction

Dry-cargo ships have cargo holds which as a rule are closed against sea and weather. For centuries this was done using a system of wooden planks covered by tarpaulins, secured by bars and wooden wedges. This often failed. The first steel hatches were MacGregor's Single-Pull system, developed during World-War II, and first installed on the Victory ships. This was a major step forward, as they were perfectly weathertight, by using rubber seals and compression bars, carefully adjusted to match each other. They are still in use on many ships.

Generally, holds have an opening at upper-deck level, surrounded by a wall, the **coaming**, to prevent water running into the hold, and to stiffen the edge of the deck. In some containerships the closing appliances are omitted. Their absence has been compensated by bilge pumps with a huge capacity.

Cargo hold covers, or **hatch covers** need to be fulfil the following requirements:
- Sufficiently strong, to withstand green water
- Weathertight
- Easy to open and close
- Maintenance friendly
- Strong attachments

Special tasks may require extra strength:
- Deck cargo such as containers or timber, with strong lashing possibilities

The **sealing system** of the various hatch cover systems is all based on the controlled compression of a rubber seal against a steel flat bar, either flat or upright.
These rubber seals and compression bars need careful maintenance as they are decisive for the weather-tightness of the hatches. Water ingress often means cargo damage.

Hatch cover types and systems are chosen based on parameters such as:
- the type of cargo the ship is designed for
- the availability of lifting appliances, on board or ashore,
- the service-area where the ship will sail,

Containerships usually have huge covers or **pontoons**, which are lifted off by the shore container crane, and stacked on top of each other or simply laid ashore.
Bulk carriers usually have side-rolling hatches, one set per hatch, general-cargo ships or multipurpose ships have pontoon hatch covers or folding hatch covers,
Ro-Ro ships have stern ramp doors, bow doors or side ramp doors, tankers have small covers, big enough only for people and tools.

2. Weather Deck Hatch covers

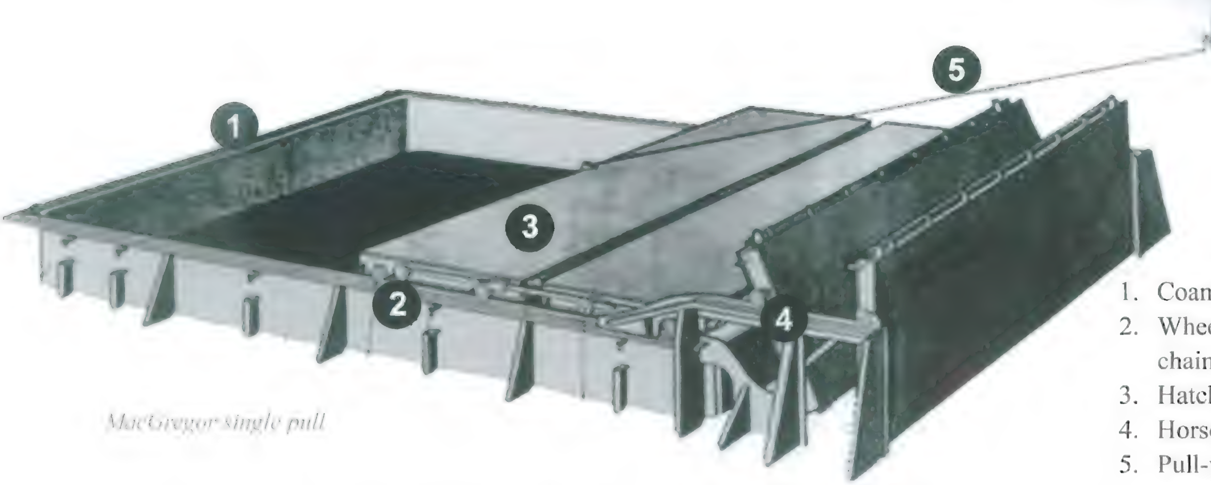
2.1 MacGregor Single Pull

During the past 50 years, the most common steel hatch cover in use was the MacGregor Single Pull steel hatch cover. Each rectangular cargo hatch is covered by approximately six transverse sections.
After being lifted from the compression bars, they can be rolled to a stowage area at the end of each hatch. There, one by one, the covers turn vertically and are stowed against each other on the guides.
Closing the covers is simply done by pulling the hatch covers towards the other end and lowering same when in position. The pulling wire comes from the ship's cargo-gear usually.
This system is used for ships up to 50,000 tons deadweight.

2.2 Pontoon hatch covers

2.2.1 General

Today, general-cargo ships upto 10,000 tons deadweight, have one large cargo hold, with division bulkheads positioned where needed.
The common hatch cover for this kind of ship (multipurpose ship) is the pontoon hatch cover. Approximately 80-90% of these vessels use this type of cover.



MacGregor single pull

1. Coaming
2. Wheels and connection chains
3. Hatch panel
4. Horse
5. Pull-wire

Pontoons come in many configurations. Often they are closed on the underside, sometimes even watertight, so that they can be stored during loading or discharge in the water, beside the ship.

The hatches (maximum weight 25 tons) are opened and closed by lifting and lowering the pontoons, with a crane on the ship or quay. The crane on the ship often is a **hatch cradle**, a traveling crane, which can also move the pontoon hatch covers over the ship in longitudinal direction, and stack the pontoons on the coaming. The hatch cradle cannot be used for cargo (see section 5).

Reasons for choosing pontoon hatch covers in combination with a hatch cradle are:

- easy maintenance - the system has no wheels or other movable parts. When in position they only need to be secured to the coaming and to each other.
- flexibility in cargo-hold configuration - movable 'tweendecks and grain bulkheads can be positioned with the hatch cradle.

2.2.2 Types of hatches

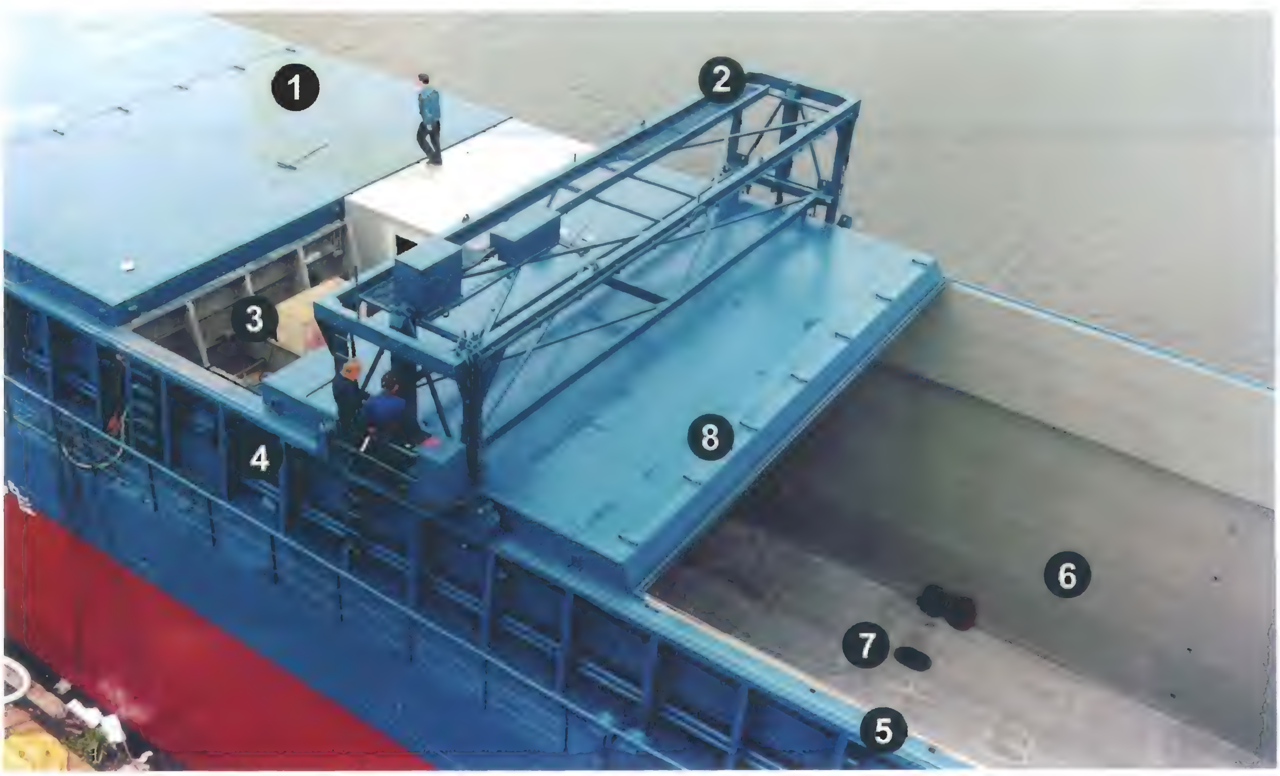
Pontoon hatch covers can be divided into closing hatch covers, intermediate hatch covers and end covers.

If a hold has to be closed, then the intermediate hatches must be closed before the closing hatches and the other way around when the hold is opened.

Sometimes there is a short hatch in between with a width of one meter or less; this is called a (hatch) beam. These are not always present or necessary. The weight of a hatch can be somewhere between 10 and 25 tons.

A beam acts as a small intermediate hatch and has the advantage that one can easily open just a part of the hatch covering. This is an advantage when it is raining. Sometimes the beam is left in place during cargo handling to absorb the deformation forces between port and starboard hatch coaming.

1. Pontoon hatch cover
2. Hatch cradle
3. Beam
4. Hatch coaming
5. Top rail
6. Hold
7. Tank top with opened manhole
8. Wedges

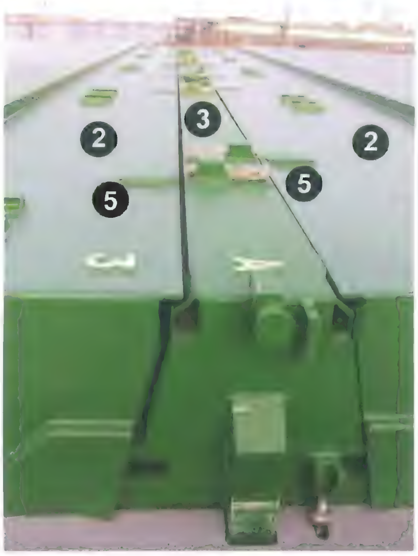


Coastal trade liner with a partially opened hatch

Longitudinal drawing of the hatch arrangement (Various arrangements are possible)

1,6,7,13	End hatches
2,5,8,10,12	Closing hatches
3,4,9,11	Bottom hatches

Multi purpose ship with pontoon hatch covers



Beam between two closing hatches

1. End hatch
2. Closing hatch
3. Beam
4. Intermediate hatch
5. Wedges

2.2.3 Positioning of a pontoon hatch

The positioning of pontoon hatch covers is achieved by **tapered pins** (centre punches) at the side of the cover, fitting into holes in the coaming top rail. On one side, the hole is a tight fit, and on the other side it allows approximately 60 mm sideways movement. As a result the pontoon hatch cover has the possibility to move several millimeter over the sliding blocks in transverse direction. This prevents the hatch from getting stuck if the width of the hold changes by a few millimeters , due to forces during loading.

Note: The sliding of the pontoon hatch cover is an apparent movement, not a real one. In reality, the top rail moves under the hatch.

2.3 Hydraulic folding hatch covers

Folding hatches are opened and closed by means of **hydraulic cylinders.** The location of the cylinder depends on its type.

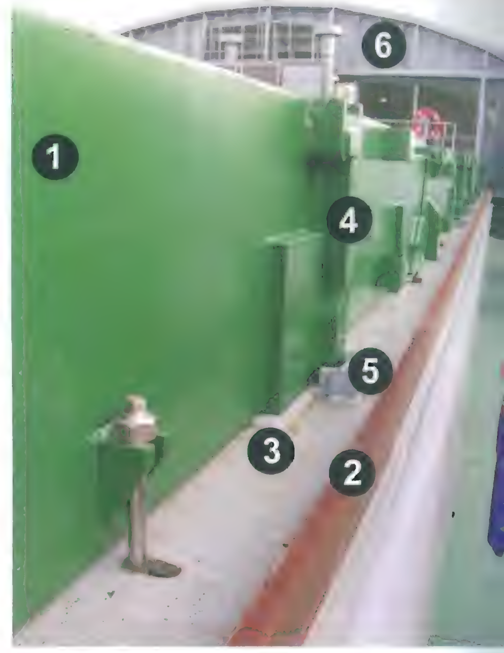
a. Cylinders attached to the outside of the hatch use the head ledge as a fixed point.
   This type is only possible if it leaves enough walking space at the deck side (minimum of 60 cm)
b. Cylinders which are supported by the beam. The pistons that push the hatch up or down are located at the main hinges.

Advantages :

- faster opening and closing compared with pontoon hatches
- the hatches can cover the hold over the entire length of the ship (there is no hatch cradle blocking their way)
  easier to control, especially in bad weather
- more hatch area per hatch; this means that there are fewer transverse seams and therefore shorter length of rubber seals (e.g. instead of 10 pontoon hatch covers, only 8 folding hatches are required).

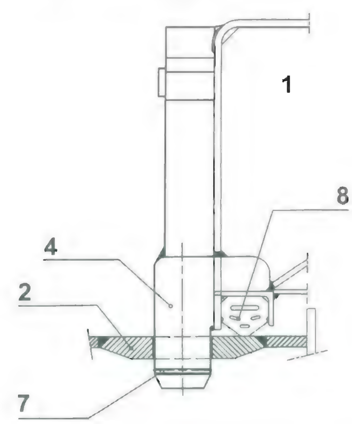
Disadvantages:

high acquisition cost
vulnerability of the hydraulic system
- vulnerable to damage by shore crane due to height.

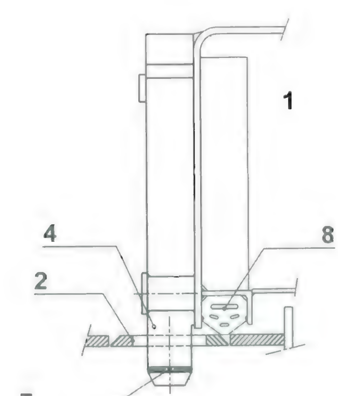


Pontoon hatch covers. Struts can be placed in the U-profiles to fasten the deck load

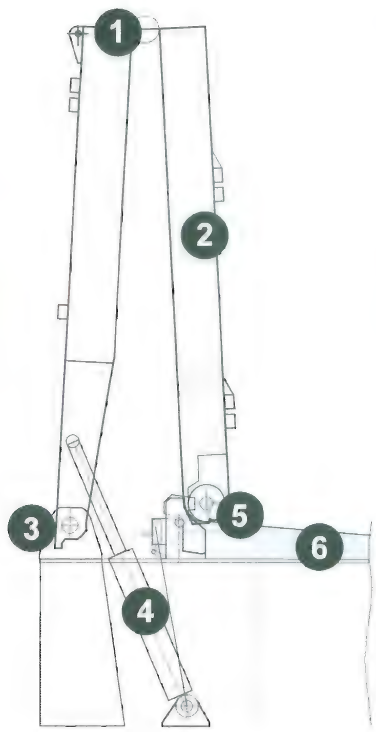
1. Hatch
2. Top rail
3. Gliding block
4. Center punch
5. Leading block
6. Wave breaker
7. Side for sealing by customs
8. Rubber packing



Immovable center, transverse direction



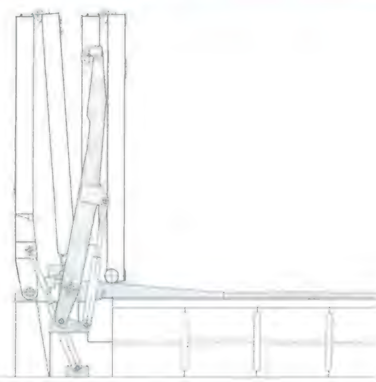
Movable center, transverse direction



Hydraulically operated folding hatches need safety devices to prevent collapse in open condition:

- ruptured hose safety system. This prevents the hydraulic system from emptying
  if the control button is released(dead man's brake), the system will stop
- For example, if the control button is on starboard a dead man's break should be installed port side. Emergency brakes can also be installed.
  a safety hook. This prevents the opened hatches from slamming shut

1. Hinges between two parts of the hatch (hatch hinges)
2. Hatch
3. Main hinges
4. Cylinder
5. Wheel
6. Ramp



Ship with opened (hydraulic) folding hatches. The ship is being loaded with timber parcels

2.4 Side-rolling Hatch covers

Large bulk carriers, ore carriers and oil bulk ore carriers are usually provided with **side-rolling hatch covers**. This type of hatch cover opens and closes in transverse direction. When in closed position, they rest on special pads, which adjust the compression of the rubber gaskets. Before they can be rolled towards the sides of the ship, they are lifted, usually hydraulically.

When lowering the hatches in the closing operation, the covers are positioned precisely by V-shaped catches, to bring the gaskets above the compression bars.

The hatches are opened and closed with chains or cogwheels. These are driven by (hydraulic) pumps located near the hatches. The individual hatch covers have to be secured to each other and to the coamings by means of bolts and/or quick-acting cleats.

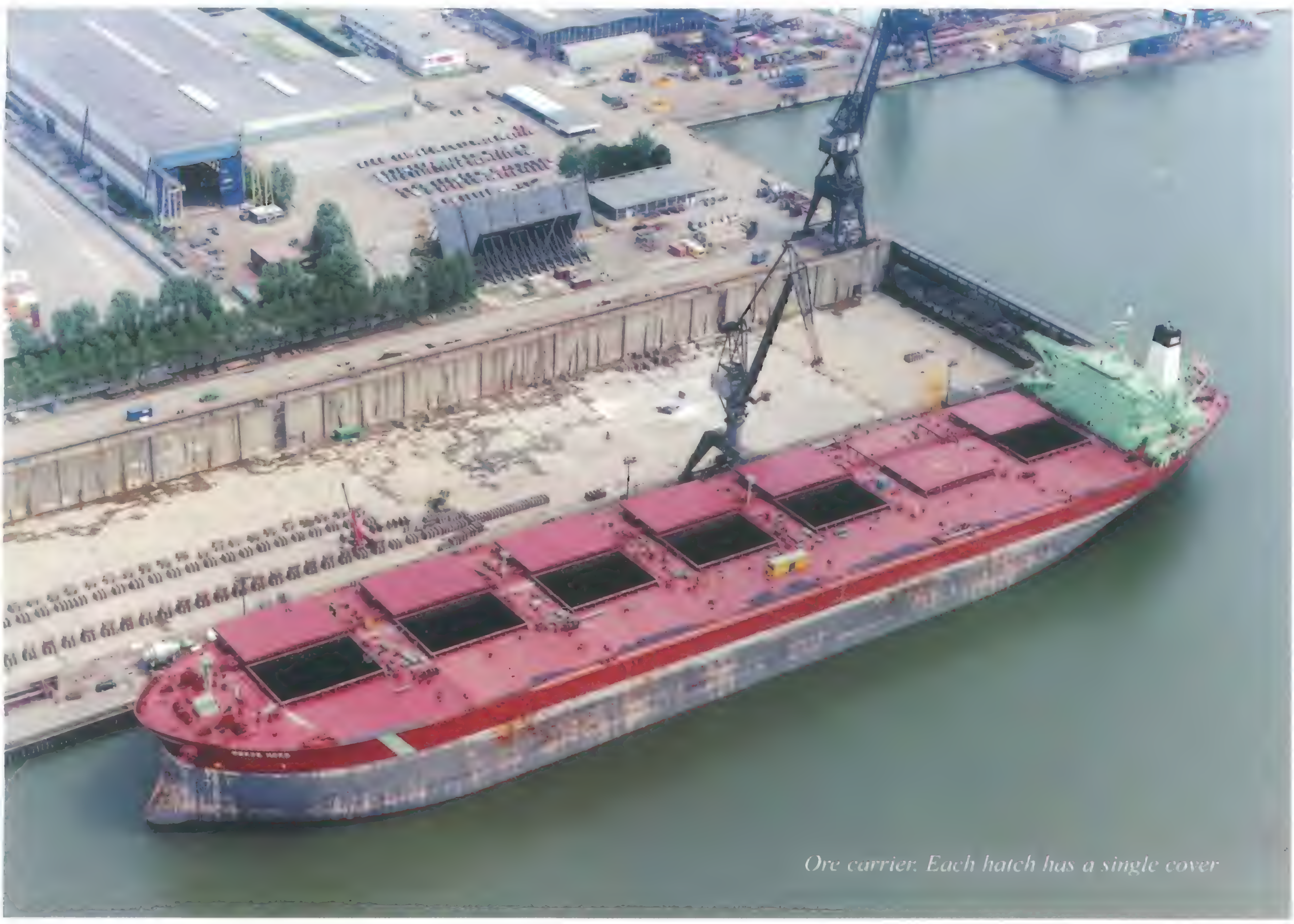
On large vessels especially, the hatch coamings have to withstand distortions of the ship as a result of the varying types of cargo and the state of the sea.

Advantages:
- minimal jointing length
- easy opening and re-closing
- low air draft of the hatch covers
- maintenance friendly

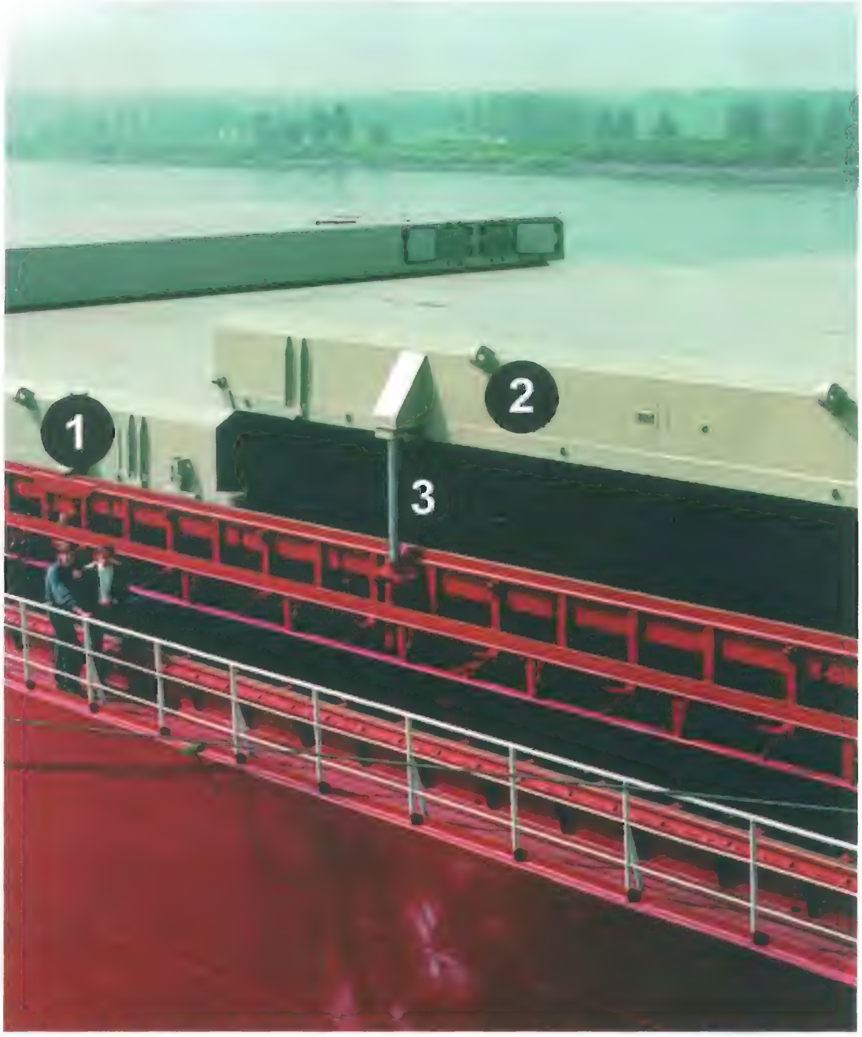
Disadvantages:
- large
- heavy

Ore carrier at sea. Each hold has a single cover

Normal bulk carrier, side-rolling hatches, two covers on each hold



Ore carrier. Each hatch has a single cover



1. Lower cover
2. Upper cover
3. Lifting plunger

Piggy back hatch-cover

2.5 Piggyback hatch covers

Another way of opening and closing of hatch covers is the fore and aft **rolling pontoon** system, called piggy-back. Two covers close the deck opening.
One cover can be lifted from the coaming by hydraulic plungers to a sufficient height, allowing the other cover to be rolled underneath the lifted cover, after which the upper cover is lowered till it rests on the lower cover.
Together they can roll, by an electric drive inside the pontoon, either above the forward half of the hold or above the aft half. The covers can have a height of approx. one meter, and a weight of 60 - 80 tons.
They are used on container ships and log carriers and are often heavily construc-ted for (heavy) deck cargo.

2.6 Open Cargo holds (No hatch covers)

Some ships have holds, without hatch covers. Some containerships, so-called **open hatch ships,** do not have hatch covers.
The holds need to be equipped with extra heavy bilge pumps to cope with any water that enters the hold. The containers in the holds prevent a free water surface. The largest quantity of water to be dealt with is not bad weather, but a tropical rain shower.
Having no hatch covers saves time needed for opening and closing.

Some types of dredgers also have open holds. There the cargo comes on board as slurry: a mix of water and sand. The sand settles, and the surplus water flows over the side. When the hold is full with settled sand, the remaining water is pumped out.

3. Distortions of the ship

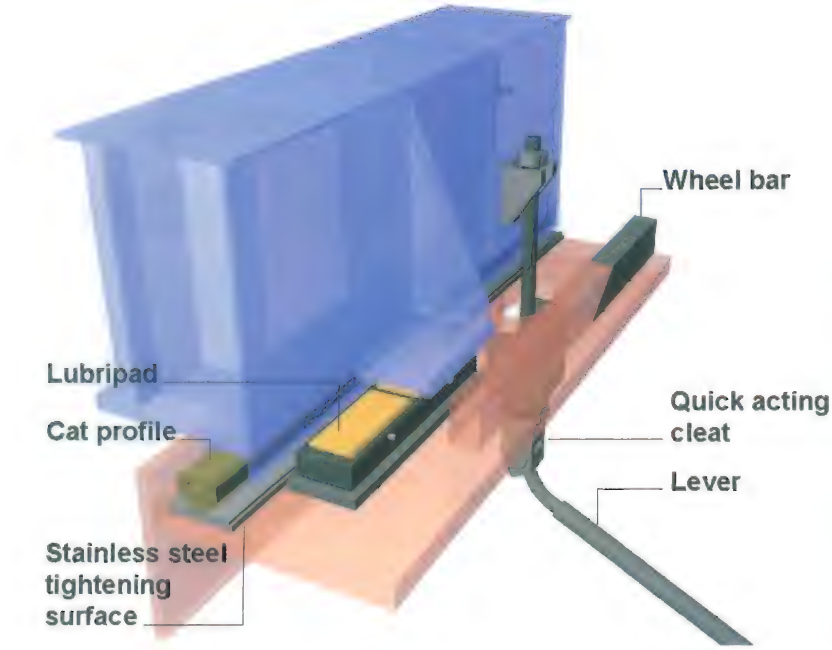
During loading and discharge a ship with a long hatch opening can become somewhat distorted. This phenomenon is called **harbor deformation**. The distortions can be prevented by placing one or more beams or hatches in transverse direction.
If, in spite of this, distortion still occurs, it can cause the hold walls and thereby the top rail to move several millimeters out of position.

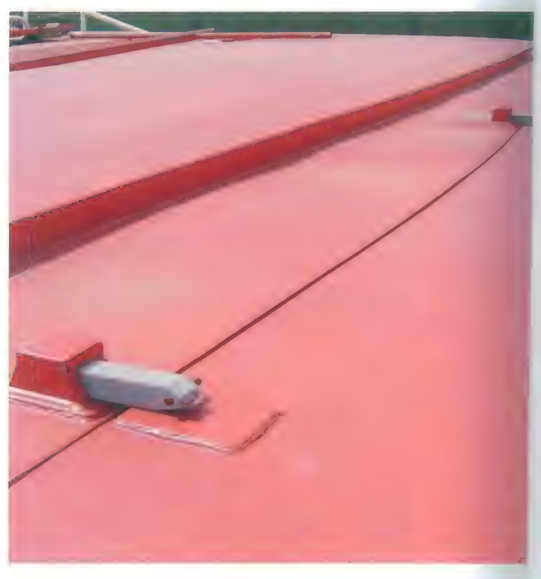
Stainless steel sliding blocks are welded onto the top rail to guide the sliding of the hatches.

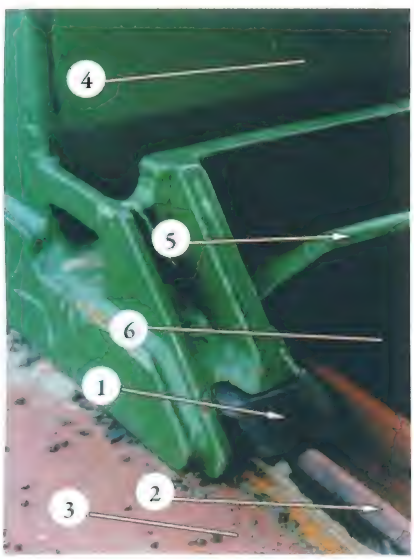
Furthermore, the sliding blocks (5mm thick) adjust the height of the covers. The sealing rubber with or without compression bar, is allowed to be pressed a maximum of 10 mm to prevent damage to the seal.
The hatches are not constructed to absorb the forces acting on a ship in waves. This is why there is a movable and fixed side.

Container ships and bulk carriers suffer from torsion in the hull, forcing the rectangular hatch openings to become a parallelogram.
The rectangular hatch covers continuously slide with the rubber gaskets over the compression bars, or over the coaming. The covers wear at the resting pad areas. Therefore, special sliding pads have been developed, consisting of layers of different materials. These pads allow sliding and carry the weight of the cover.

Greasing the rubbers before closing the hatches helps reduce wear.







Intermediate hatch

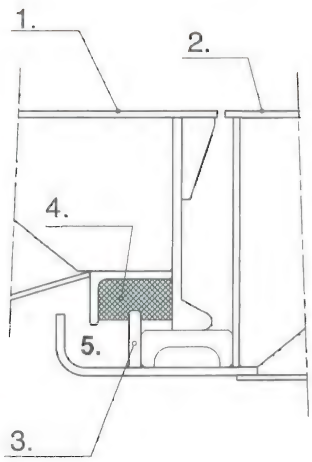
1. Rubber gasket
2. Compression strip (fore and aft)
3. Top rail
4. Pontoon hatch cover
5. Compression strip for the circumferential seam sealing
6. Hold

4. Weather-tightness

Hatch covers have to seal the hold weather-tight. This weather-tightness is achieved by:

4.1 Rubber sealing gaskets

Rubber sealing gaskets, glued in a channel in the cover rest with **controlled compression** on the coaming, on a flat surface or on a vertical



Circumferential seam sealing

1. Closing hatch
2. Intermediate hatch
3. Compression bar
4. Rubber gasket
5. Gutter

compression bar. The compression is controlled by **resting pads**, adjusted in height, to obtain the desired compression.
The sealing gaskets have a backup in the form of a save-all, a gutter, collecting the drops of water that managed to pass the rubber gaskets. Often this gutter is double installed.
This save-all is fitted between the rubber and the coaming edge, and between hatches in transverse direction, below the jointing rubber, leading the leakage water to the coaming. The corners of the coamings are provided with a drain.

4.2 Cleats

Cleats on the outer edge of the pontoon hatch cover fix the hatch cover to the coaming (see picture quick acting cleats).

4.3 Wedges

Wedges - to adjust the compression of transverse joints.

4.4 Checking Weather-tightness

Hatch covers have to be checked for tightness regularly. It can be done as follows:
- The hose test. A powerful jet of water is sprayed against the joints of the pontoon hatch cover, while the hold is simultaneously checked for leakage.
- With the aid of ultrasonic detection equipment. A transmitter of sound waves is placed in the hold along with a detection microphone (receiver) on top of the hatch cover or moved along the coaming. If the detector does not 'hear' a sound at the transmitted frequency, the hatch is considered watertight.

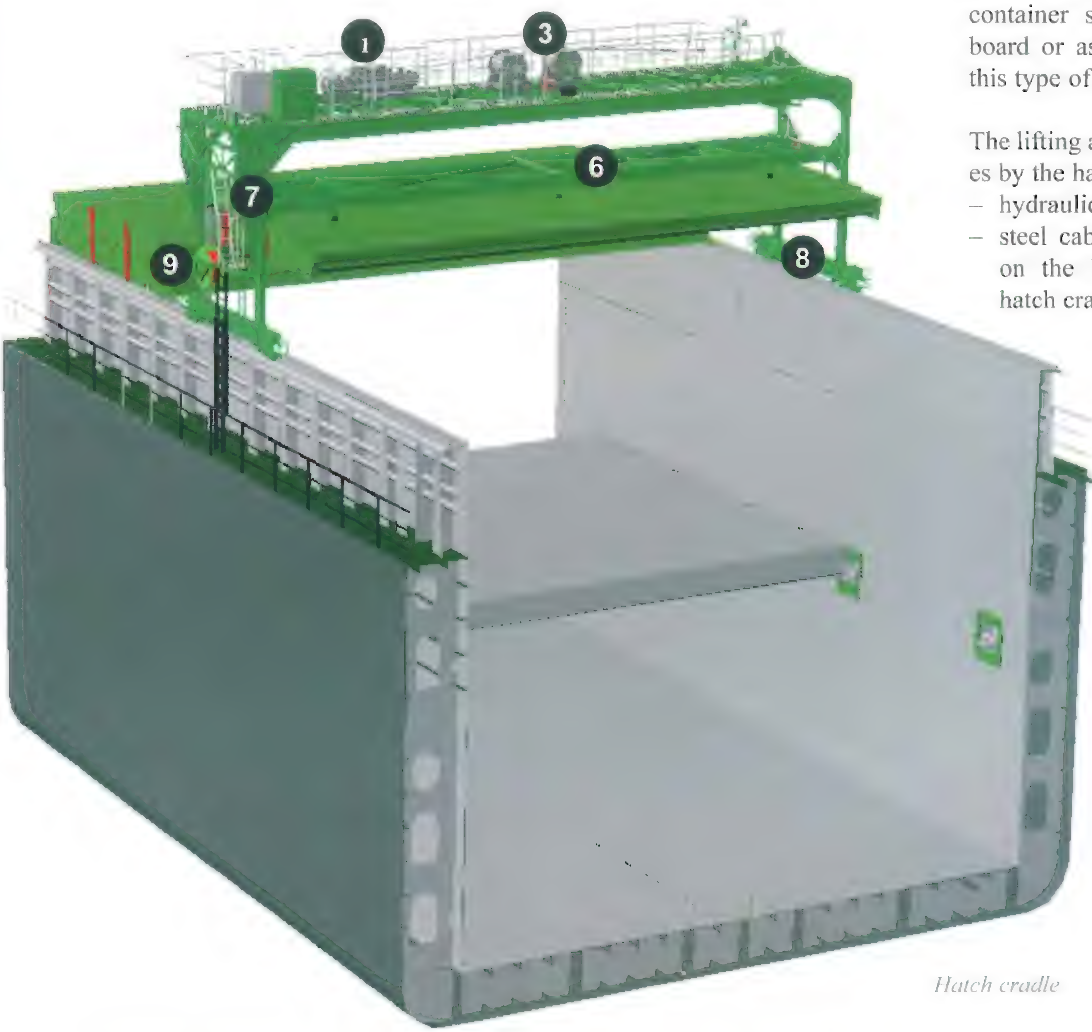
Checking the tightness of hatch covers is commonly performed by charterers and P & I clubs prior to loading.
It is the normal test when the ship is new, during commissioning, at **Annual Survey**, at **Special Survey** or after repairs when the Classification inspects the hatches.

1. Electro-hydraulic pump
2. Control box
3. Winches with steel cables for pontoon lifting
4. Stores crane
5. Control bob stores crane
6. Movable bridge
7. Columns
8. Wheel with hydro motor. Two of the four wheels are equipped with brakes.
9. Reel for the feeder cable

5. Hatch cradle

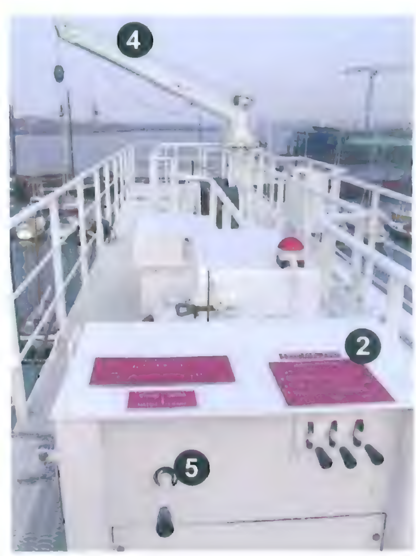
Ships that are equipped with pontoon hatch covers generally have a hatch cradle to open and close the holds. Ships with a carrying capacity of more than 10,000 tons (especially container ships) need a crane (on board or ashore) to open and close this type of hatch.

The lifting and lowering of the hatches by the hatch cradle is done by:
- hydraulic cylinders (up to 14 tons)
- steel cables operated by winches on the loading platform of the hatch cradle (up to 21 tons)



Hatch cradle

Top view of the hatch cradle, fixed bridge



Top of the hatch crane

Hatch cradles are usually equipped with two stores cranes. These cranes are capable of:
- loading and discharging provisions and engine parts
- lifting materials in and out of the hold
- carrying materials over the entire length of the ship.

This crane can rotate 360°, but cannot be topped or lowered.

With the cradle one can also operate the working tray for work in the hold, such as:
- handling grain or separation bulkheads
- handling the supports for the tweendecks

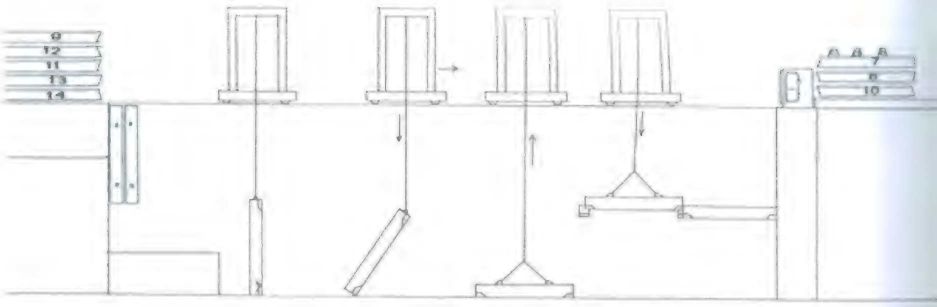
The height of the working tray in the hold can be controlled by the person operating it. The steel cables that control the movable bridge can be disconnected and attached to a bulkhead.
These bulkheads can then be positioned anywhere in the hold by the hatch cradle. The bulkheads can then be used as tweendecks or separation bulkheads.

Safety on the hatch cradle:
- an optical signal with a bell if moving
  emergency stops on the hatch cradle:
  - on the loading platform
  - the bottom side near the gangway (P and SB)
  - speed brakes in the hydraulic system will immediately come into action in case of a hydraulic leak.

6. Tweendeck Hatches

Tweendeck hatches come in the following versions:
- pontoon hatch
- folding hatch

Tweendeck hatches are normally not provided with gaskets.



This drawing shows how, with the aid of the hatch cradle, the bulkheads can be placed in different positions.

Cargo hold of a multi purpose cargo ship, divided in two parts, using the movable bulkhead. The forward part for bulk cargo, the rear for packed cargo.

6.1 Pontoon hatch

Pontoon hatches are usually found on multipurpose ships where their function is twofold (see chapter 8.1). Pontoon hatch covers can be placed both horizontally (tweendeck) and vertically (grain or separation bulkheads).
The positioning of the pontoons is done by the means such as a hatch cradle or crane. If the pontoons are not in use, they are stored vertically, in special stowage.

6.2 Folding hatch

Tweendeck folding hatches are common on ships which are provided with more than one tweendeck, such as reefers.
On reefers having three tweendecks, there is usually one tweendeck where the folding hatch is fitted with thermal insulation. The folding hatches of tweendecks are normally operated mechanically. The cargo runner of the crane is used to open the hatches.

Tweendecks with folding hatches on a reefer.

A ship's crane opens a folding hatch.

7. Entrances

7.1 Side doors

Side doors are found on ships with a large freeboard, like passenger liners. These vessels use this door to embark and disembark passengers. Larger side doors (ramps) are used to load and discharge vehicles. Generally, these doors are controlled hydraulically (see chapter 9). A side door locally weakens the strength of a ship. This has to be compensated for by thicker side shell plating and heavier internal structural parts.

7.2 Stern Doors and Ramps

Ro-Ro vessels often load and unload via stern doors and quarter or slewing **ramps,** combining the function of bridge between jetty and ship and watertight closure of the cargo-hold. Due to the weight of the lorries, these doors/ramps are heavily constructed. They are supported at the stern of the ship in the hinges and jetty. The span can be considerable.
Opening and closing is done by wires, via hydraulic cylinders and jigger-winches. The hoisting wires are often backed up by a heavy wire or chain, to prevent lowering too far in case of wire or hydraulic failure.

7.3 Bow Doors

Ro-Ro passenger vessels on short voyages, such as Cross-Channel services also have bow doors. There are various types - horizontal sliding doors, vertical doors, and ramp-door combinations.
The latter type is often protected by a bow visor, where the whole bow opens upwards, giving access to the ramp, the real watertight door.
After a number of accidents, the strength and security of the various systems have gotten much attention, and requirements have become more and more stringent.

Ro-Ro ships also have ramps between upper car deck and lower car deck. This ramp when closed, is part of the upper car deck and also part of the weather-tight closing of the ship. These ramps are therefore, provided with rubber gaskets.

An opened side door, equipped with hydraulic cylinders for opening and closing.

7.4 Companion hatches

Companion hatches come in many shapes and sizes. Some types are discussed below. Storage compartments often need a wide entrance because the stored parts, such as engine parts, lashing gear, etc. can be quite large. The companion hatches can be opened manually or with the aid of a crane, a hatch cradle or a hydraulic system.
Companion hatches on oil tanks can be sealed from open air with a cover that makes the hatch impermeable to oil and gas. The cover itself is closed with clamps. Just above the cover is a screw-thread on a wheel that is used to lift the lid and subsequently turn it away from the hatch coaming.
The hatch covers are sometimes provided with a smaller hatch that is used to take samples and determine the ullage and the temperature of the cargo.


Hydraulically controlled entrance hatch

7.5 Accommodation doors

Exterior doors
Exterior doors are weather-tight. This means that, if the door is closed, it will only leak when submerged in water.
The exterior doors are often opened and closed with a central bar or wheel, serving up 60 toggles. The difference in the exterior doors shown below is the number of closing points. This determines the quality of the tightness.

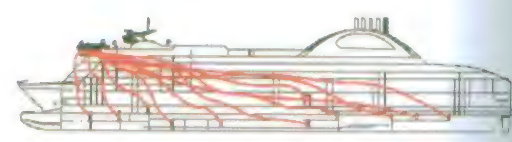
Interior doors
These doors are inside the weather-tight doors. Fire fighting regulations require that there is a fire barrier in the accommodation. This can then be achieved by using metal fireproof interior doors, automatically closing in case of an alarm.

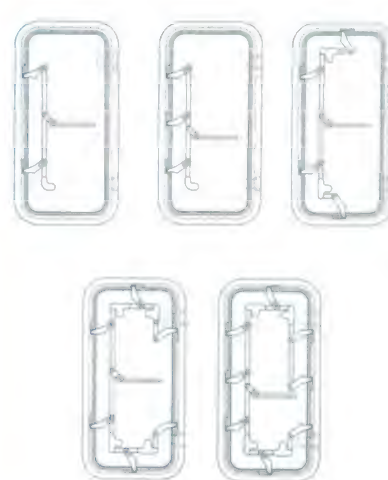
A watertight door

7.6 Watertight doors

These are really watertight closing appliances, used in watertight bulkheads, for instance between engine rooms.
They are designed to withstand water pressure, depending on the height they are installed. Watertight doors can be controlled locally, manually and hydraulically, as well as on the bridge. The control panel on the bridge indicates if a watertight door is opened or closed. The doors are operated hydraulically. Even if the whole compartment is filled with water, the watertight doors should not leak.


Weathertight door


Overview of the watertight doors that can be controlled from the bridge


Types of outside doors that can be opened with just one bar

8 Miscellaneous

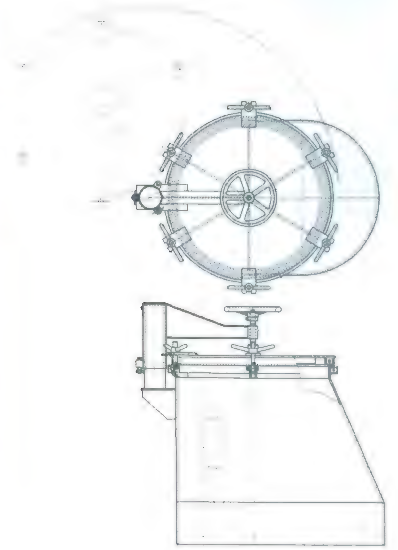
8.1 Ventilation Louvers

All the vents of the holds, the engine room and the accommodation are shielded by gratings, often louvers. These have to be provided with means for closing weather-tight and air-tight by a cover in case of bad weather or fire.

Manhole cover of top wing tank nr 1, portside, in the main deck of a bulk carrier, looking aft.

Ventilation louver with cover

Ventilation louver for the accommodation



Cross section and top view of a cargo oil hatch with cover

A rotating cover on a cargo oil hatch

8.2 Manhole Covers

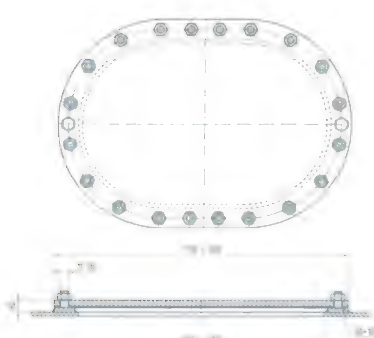
Manhole covers close the access openings that are part of every tank, except for the cargo tanks. Manholes make it possible to inspect a tank.

8.3 De-aeration devices

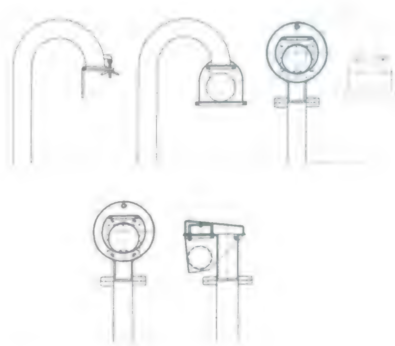
- **Tank vent / overflow**

Every liquid-containing tank must have a means of venting in order to prevent over and under-pressure during emptying or filling. For this purpose, every water and oil tank has **venting** that ends on the freeboard deck at a vent terminal with a closing device, preventing seawater entering the tank.

In case of submersion of the tank bleeder (due to large waves), a floating ball inside the tank bleeder will float upwards until it is pressed against a rubber ring.

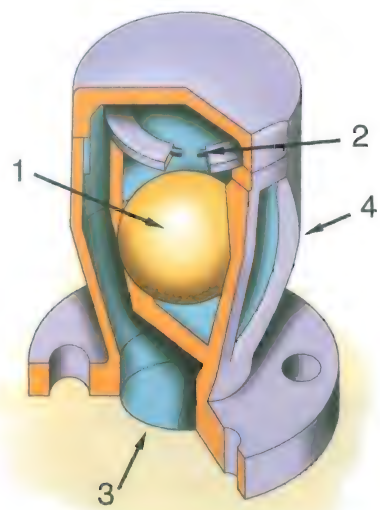


Cross-section and top view of a manhole cover



Some types of vent terminals

Raised tank vents



Drawing of the inside of a vent terminal

1. Plastic ball
2. Rubber gasket
3. Vent opening
4. Air and water release pipe

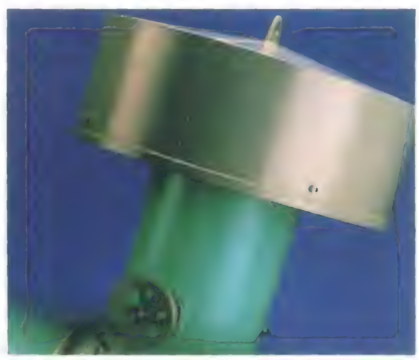
This mechanism seals the pipe from the seawater. When, the tank is overfilled, the surplus water or oil discharges via the vent terminal on deck. Tank vents / overflows can be equipped with:

- an overflow, capable of guiding the contents of the tank to another location
- a sounding opening where the depth of the liquid in the tank can be measured
- in case of a vent / overflow of an oil-tank, a flameproof mesh and a save-all to keep oil inside is compulsory.

Cargo tanks of tank vessels have complicated venting system, in connection with inert gas and the influence of outside temperature on the pressure of the possible huge gas quantity in the (empty) cargo tank.

- **Mushroom shaped vents**

Mushroom shaped vents are only used for the ventilation of dry spaces like the bosun's store or the accommodation. They have to be provided with a fire flap for protection against fire or bad weather. Often the whole mushroom head can be screwed down to close the vent. There are two ways of closing them, either manually rotating the top part or with a valve. They are a mechanical back-up when the air conditioning does not work; under normal circumstances they are closed.



Mushroom shaped vent with a hand wheel

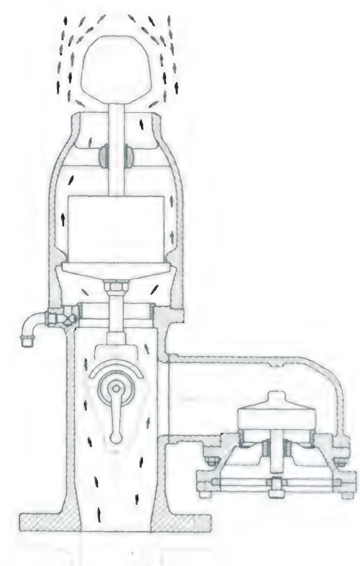
- **High speed pressure valves**

High speed pressure valves are tank vents with the special characteristic that they let the gas escape only when a certain **over pressure** is reached, and not before that. The velocity of the escaping gas is so high (with a minimum of 30 m/sec) that it can never catch fire. The gas rapidly diffuses into the air and will not fall back to the ship.

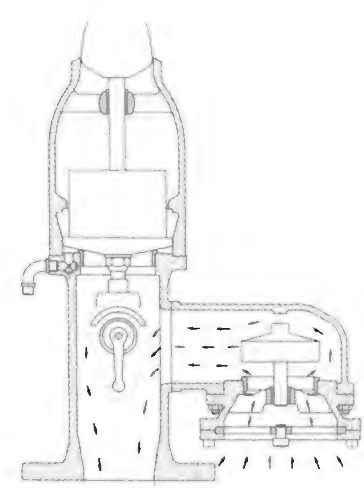
Pressure / vacuum valve (P.V. valve)

They will also let air into the tank in case of **under pressure**, for example during the emptying of the tank. To ensure that no flames can get inside of the tank via this route, a fire-resistant wire mesh covers the inlet side of the valve. The type of high speed pressure valve discussed here is the most widely used type on tankers. It is a safety device against over or under pressure, which ought to be taken care of by the inert gas system, or damp-return system.

All the parts mentioned in this section are either bronze, galvanized or stainless steel. The classification society determines which type of material is to be used.



High speed pressure valve. The arrows depict the path of the escaping gas.



High speed pressure valve. The arrows depict the path of the gas flowing in.

9. Coming on board / access to the ship

Accommodation ladder

Every ship needs means of getting people on board safely. Most vessels have two accommodation ladders, one starboard and one portside, preferably where the ship's side is flat. In general, the accommodation ladder is made of lightweight aluminium that makes it easy to handle. The top of the accommodation ladder is attached to a platform with a slewing connection, so that, if necessary, it can be turned away from the ship in case of a large gap between the ship and the quay. On the quay the accommodation ladder rests on a roller, at the bottom of the stairs. This roller allows the accommodation ladder to slide on the jetty as a result of changes in draft or movements of the ship. Lowering and lifting of the accommodation ladder is done by a winch.

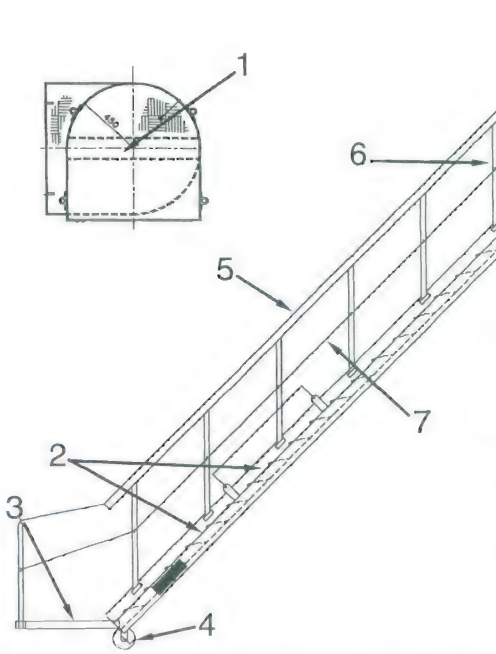
Compulsory safety measures:
- a safety net hanging under the gangway
- a life buoy at the gangway with light and line

- **Gangway**

Many vessels have an aluminum gangway in addition to an accommodation ladder. This gangway is used whenever the accommodation ladder cannot be used, reason of location or jetty lay-out. The gangway is put into desired position by either a crane or manpower.

Unfolded accommodation ladder

Gangway on a passenger liner



1. Top platform
2. Steps
3. Bottom platform
4. Roller
5. Handrail
6. Stanchion
7. Synthetic rope
8. Steel cables attached to the winch

Side view of an accommodation ladder and top view of the platform

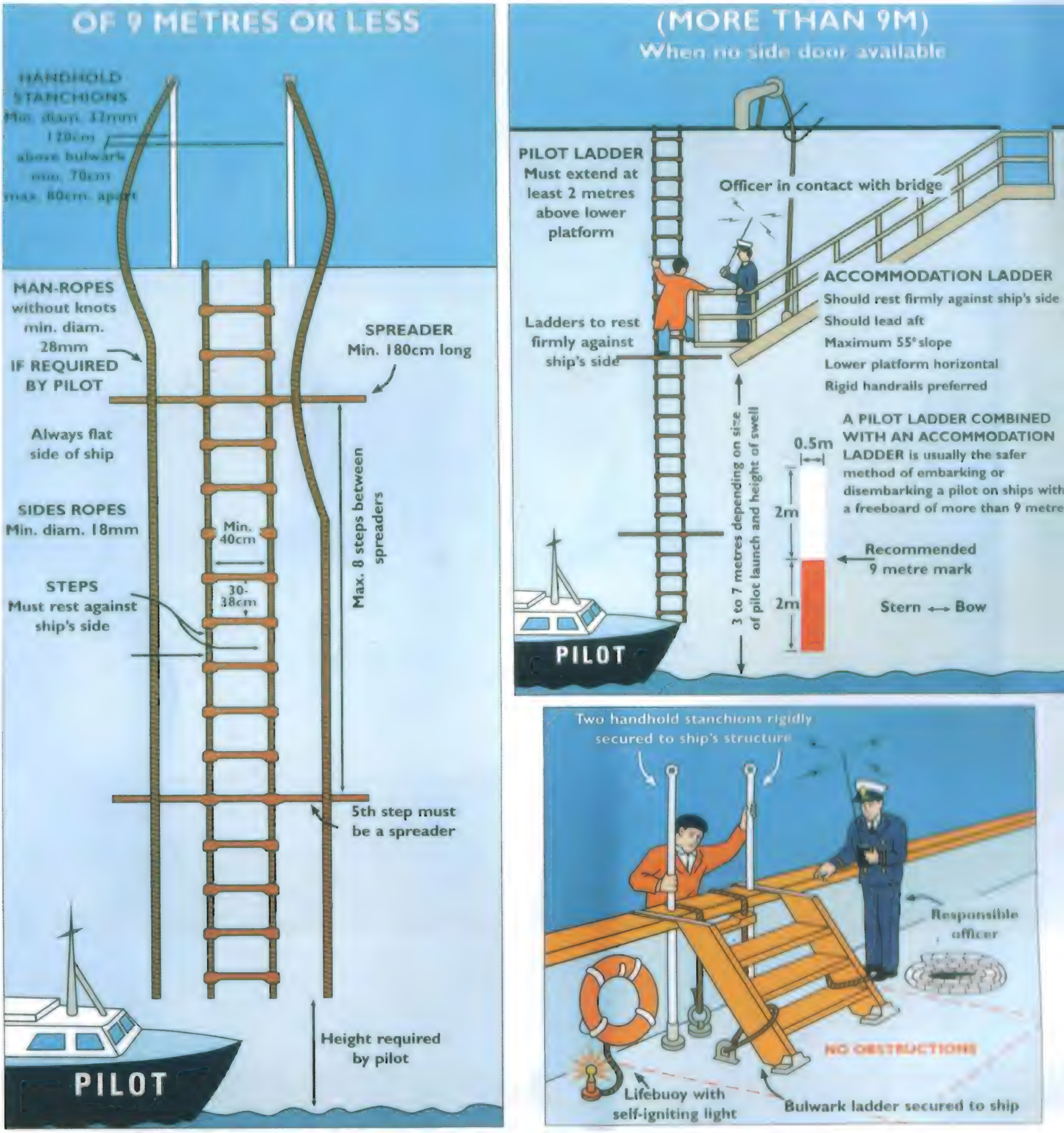
Loadtest of an accommodation ladder using water bags. 75 kgs / step

– **Pilot ladder**

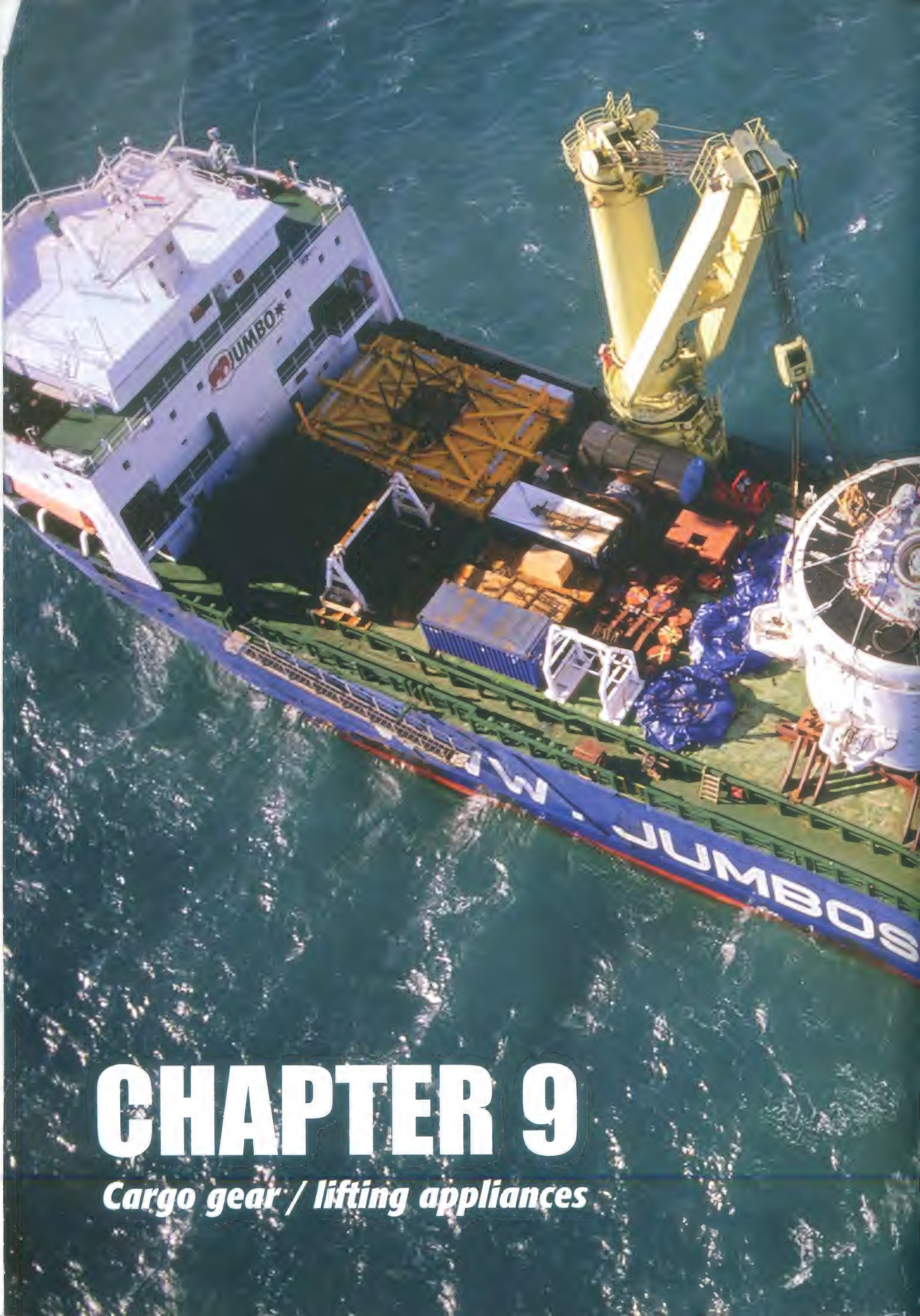
A pilot ladder is a **rope ladder**, with flat steps, and spreaders to prevent turning of the ladder. On large ships with a high freeboard, the ladder is installed in combination with the accommodation ladder.

There are strict regulations governing pilot transfer.
There are regulations for the pilot ladder, the bulwark ladder, safety and the ways in which these are arranged.

The pilot can refuse to use the pilot ladder if the position or quality of the ladder is not in agreement with the regulations.



This drawing illustrates how the pilot ladder and all the auxiliaries involved should be positioned in order for the pilot to safely board the ship. Taken with kind permission from: "Witherby & Co.LTD" in London



CHAPTER 9

Cargo gear / lifting appliances

SHIP - NL

SHIP KNOWLEDGE

Covering Ship Design, Construction and Operation

QUESTIONS:

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1. Onboard cargo handling gear

Transshipment is moving cargo into and from a means of conveyance, like a ship or a truck. Most cargo is moved with the aid of some type of **cargo handling gear**. Only very small and lightweight cargo is still moved by manpower. The cargo handling gear is either present on the ship (self-loader/unloader) or at the port. In the latter case the quay has a large array of mobile cranes capable of moving along the length of the quay. These cranes used to move exclusively on rails, but today an increasing number of cranes are equipped with ordinary wheels with air tires and steering capabilities. This allows the cranes to move freely across the entire quay / port.

1.1 The choice for on board cargo handling gear

There are many types of cargo handling gear for ships and just as many incentives for choosing to install one or the other:

A mobile crane on pneumatic tires

- The charterer (who hires the ship) demands it. Why, is not the shipping company's concern, but if not in possession of a self discharging ship, the order goes to a competitor who does have one!
- The area of navigation demands it because the ports in that area lack cranes. This is often the case in Africa, South-America, Asia and in small ports and factory sites all over the world.
- In order to transport special cargo too bulky or too heavy to handle with the available shore cranes.
- Special cargo is a one-time, large scale transport like a complete factory, moved in sections, or large and heavy machinery.

Ship's cranes reduce the stability and the carrying capacity of a ship; they also cost money and require maintenance.
On a general cargo ship, two cranes, including foundations, represent 10% of the total building costs.

Mobile crane loading paper rolls stowed on a pallet and handled further by a special forklift

Container cranes on rails at work

Refrigerated vessels often have 7 or more (light) cranes on board which may cost as much as 20% of the total building costs.

As a compromise it is possible that a ship is built without cranes, but with the necessary foundation (strengthening in several places on the ship) and piping systems.

If cranes are then required, they can be installed without radical changes to the ship and without extra loss of time (if the cranes are ordered in advance).

1.2 Statutory demands

The statutory demands for cargo handling gear, including lifts, ramps, hoistable decks etc. are laid down in the **ILO-convention** 152 (International Labour Organisation).

Compliance with the regulations is under the supervision of the flagstate and the Classification Societies like ABS, GL, Lloyd's and Veritas.

Classification of cargo handling gear is regulated by:

- National law, which states that the ship checks the gear annually and a **class check is done every 5 years**.
- International regulations which state that the gear has to be checked **annually** by the Classification Society for an examination and a function test. Once in five years a **Quadrennial Survey**, i.e. a yearly examination, including opening up of blocks, etc. plus a load-test.

Division of tasks.

The inspections, certification and responsibilities are divided as follows:

- All ILO-152 tasks directly related to cargo handling (cranes, ramps etc.) are the responsibility of the Classification Society.
- All ILO-tasks related to safety, such as entrance to the ship, hold or crane entrances and safety in the holds as well as supervising the Classification Societies are the responsibility of the flagstate.

All tasks that do not result from the ILO-152 treaty such as hoisting gear in the engine room, store cranes, etc., are the responsibility of the shipping company, in compliance with national law and ISM.

Certificates

The items under control of the Classification Society are specifically mentioned in the Register of Ship's Lifting Appliances and Cargo Handling Gear.

Excerpts from the ILO-152 treaty:

Every seagoing vessel must have a **Register of Ship's Lifting Appliances and Cargo Handling Gear.**

The inside cover of this register must state:

The rules for the five-yearly inspections as stated in the ILO-rules and the rules of the Classification Society.

- Rules for the annual inspections
- Test certificates must be present for all parts of the loading gear that can wear through use and aging:
  - the crane (complete)
  - the runner and topping lift wire(s)
  - the blocks and sheaves
  - the hoisting winch
  - the crane hook
  - attachments

  The certificate must show which requirements are applicable for every part.
- Certificates are marked by the surveyors name stamp, covered by his signature and the date and place of testing.

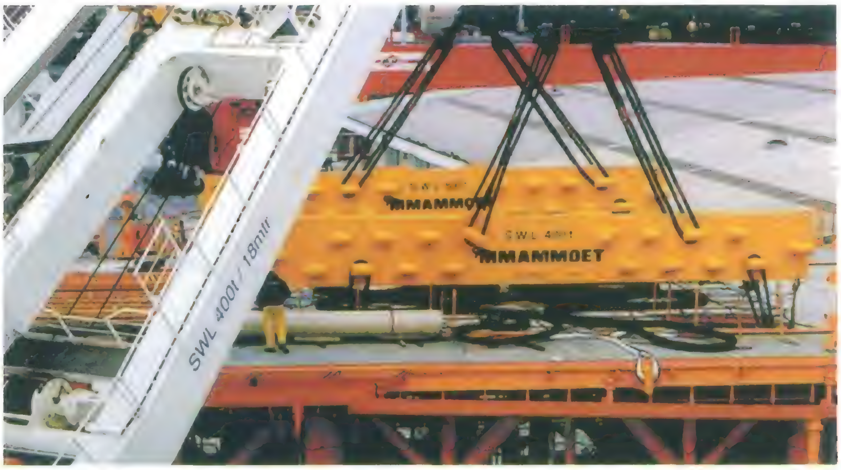
  The bottom of the jib must show:
  - the maximum Safe Working Load (SWL).
  - the radius applicable to the load (the horizontal distance between turning point and vertical runner)

These figures must be clearly visible from where the cargo is hooked on to the cargo hook.

Example:

SWL 60 t (40 t)/16 m (28 m)

SWL is 60 tons with a radius of 16 meters and 40 tons with a radius of 28 meters.



Indication of SWL and range of a large shear legs floating crane

2. Slewing cranes

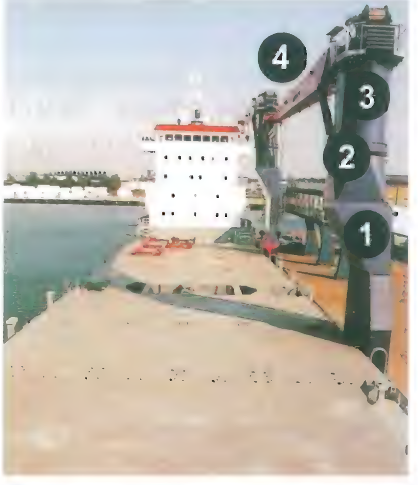
The picture on the right shows a ship with three common slewing cranes. The crane house is bolted to a **slewing bearing**, whose lower ring is bolted to a pillar, the foundation, which is part of the ship's construction. The slewing bearing is a large double-turning bearing. An electric or hydraulic motor grabs in the rim of the upper turning ring with its pinion, which is a large ring-shaped cogwheel that rotates the crane. Normally the crane cannot rotate unrestrictedly due to electrical cables running to and from the crane inside the pedestal.

Container feeder with revolving deck cranes

The crane cabin is a steel construction with windows that allow the crane driver a wide view of the area of activity. The wire drum(s), drive engine(s) and the controls and security are all located in the crane house. The diameter is 2-3 meters.

The crane jib is hinged to the crane house, making lowering and topping possible. The crane jib consists of one or two box beams. The jib is designed in such a way that it has the desired strength, while its weight is minimal and its stiffness is maximal. The different types of revolving cranes that are discussed can be distinguished mainly on the basis of where the jib is attached to the crane house.

Deck crane



Feeder with deck cranes

1. Crane foundation / pedestal
2. Slewing bearing
3. Crane house
4. Jib
5. Jib-crutch or boom rest
6. Topping cylinder

2.1 The position of Cranes on the ship

Masts and cranes used to be placed exclusively on the centerline, but today they are increasingly moving towards the side of the ship.

The following remarks can be made:
- Positioning on the centerline of the ship is best for the ship's stability. With cranes at centerline, the crane driver has a good view of the holds, but not of the quay. There is also no preference on with which side the ship should come alongside.
- If all the cranes are positioned on one side of the ship, there is an adverse effect on the position of the ship's center of gravity. Therefore, only large ships, where the mass of the cranes is very small compared to the ship's total mass, can have this kind of arrangement. For the crane driver the view of the holds is not good compared to when all the cranes are on the centerline, but the view of the quay is greatly enhanced. In addition, the reach of the crane on the quay is also much improved.

An alternative is to position one crane on portside and one starboard, (or two and two, alternating). They are still off center, but now half the number of cranes are not on the side of the quay, which is bad for visibility and the reach of these cranes.

If **remote controls** (wireless) are used, the view from the crane cabin is of no importance. The crane driver can position himself wherever the visibility is best.

2.2 Securing the Cranes

All crane jibs are subject to additional forces from waves. Therefore jibs have their own cradle, a support where they can be secured during the voyage. This can be done by means of:
- a fixed or moveable support somewhere on deck
- a fixed support against the forecastle a deck house, the groyne or the poop deck
  a neighboring crane as support if the crane jib's length equals the distance between the two cranes
- a support against the crane cabin to which the jib can be fastened when the crane is not in use

2.3 Load control

a. Slewing velocity
Revolving cranes often have a long cargo runner (hoisting wire) to which the load is attached, especially at short range (when the jib is near vertical). If the crane rotates, the initial velocity of the load will be less than the velocity of the jib. The velocity of the load then increases. When the jib reaches its final position and stops, the load will still have momentum, which sends it past the position of the jib. The skills of the crane driver ensure that the load arrives at the intended location.

An objection to the revolving crane is that the horizontal momentum of the load makes it difficult to accurately position the load. Therefore, high loading and discharge speeds cannot be obtained. In many cranes with a large range, the angular velocity, when revolving, is reduced automatically in connection with the following:
- The forces of accelerating and decelerating increase with the square of the range.
- Centrifugal forces, which give the load the tendency to leave its circular trajectory, increase as a function of the crane's range.
- Crane drivers can control the load up to a maximum angular velocity of 2.5-3 m/s.

b. Lifting capacity
The maximum pulling capacity of a drum winch is, on average, 10-25 tons. If the jib is lowered and the radius of the crane increases, the load, hanging from the end of the jib, increases the moment on the crane (tipping moment). For this reason, the maximum load of all cranes depends on the radius (inversely proportional). In some cranes, the maximum pulling force of the winch is automatically reduced when the radius increases. This prevents loads from lifting when the radius is too large. (load/momentum limit).

c. Lifting velocity
With some cranes it is possible to switch the winch manually from **single work** to **double acting**. In double acting, the maximum pulling force is larger and the lifting velocity smaller (inversely proportional). Often this switching is automatic; if the crane has to lift too heavy a load it will switch to double.

Midship deck cranes (SWL 40 tons and range 28 meters)
1. Support on deckhouse
2. Support on the fore mast

2.4 Ship stability

When working with cargo gear and especially with heavy loads, the stability (GM) of the ship must be positive to such an extent, that it remains positive when the load is suspended from the crane.
The ship's initial stability prevents cranes from listing more than 5°. Too great a list can be prevented or reduced by shifting ballast water (or fuel).
In many ships this is automated by an anti-heeling system that automatically pumps water from one wing tank to another, during the moving of a heavy load from port to starboard, or vice versa. The working angle limit of cranes is normally 5° .

In general, revolving cranes are hardly affected by trim (the difference in draft fore and aft). Most cranes can tolerate a trim of 5°, but there are also cranes with a maximum trim of 2°.

One of the reasons for a maximum list and maximum trim is that the slewing engine must overcome a larger part of the load's weight (this increases with the sine of the crane's angle with the vertical).

2.5 Safeguards

Some safety devices of revolving cranes are typical for these types of cranes, others apply to all crane types.
General rules:
- A **zero voltage device** shall be present. No power to the various electric motors means that brakes are applied. If the power supply is restored after it has been interrupted, the crane will not start on its own. A normal safeguard is the automatic main switch. It can be turned on again when the crane driver is back in place and resets the controls.
- An overload safety shall be present. If any part of the crane experiences an overload, it is immediately shut down. In case of an electrical crane motor any overload should also activate the brakes.

If this does not happen, the load or jib drops, and when the crane is revolving it is be difficult to stop.
Emergency stops shall be present. Red emergency stop buttons shall be present within reach of the crane driver and wherever the regulations require them. When pushed, all movement of the crane is made impossible. Emergency stops can only be reset locally.
A **hoist-limit** switch shall be present. This is a switch that defines the highest position of the hook.
- **Empty drum** safeguard. The hoisting cable shall be wrapped around the drum at least three times in order to keep sufficient lifting capacity (friction).
Sometimes an **inclination limit switch** is present. This shuts down the crane when the angle of inclination becomes too large.

Specifically for revolving cranes:
- A limit switch for the highest and lowest position of the jib. This is also the maximum and minimum outreach limit.
- Turning limit switch(es) to prevent the crane jib from touching another part of the ship's structure.

2.6 Drives

Every crane has at least three motors: one for the runner, one for the topping of the jib and one for slewing. The motors can be hydraulic or electric. In case of hydraulic power to the crane, the hydraulic supply is created by a so-called power-pack, driven by an electric motor.

a. Hydraulic crane drives

The runner and the slewing both require revolving hydraulic motors; the topping of the jib is done using one or two hydraulic cylinders. The main slide valve is controlled with the main lever via the driver valve. The motor automatically stops moving when the crane reaches an extreme position. This is done with the aid of a limit switch and an end switch, although movement in the opposite direction is still possible.
To lay down the jib in the crutch, the resting position, an override switch is necessary, as this is normally below the lowest allowable position of the jib.
The main slide valve often has a very ingenious construction adapting the force and velocity of the winch engine to the position of the control lever. The main slide valve also lifts the brakes of the particular motor when movement is wanted. Furthermore, if the oil lines of a hydraulic motor are closed, the main slide valve can absorb the extra load.

b. Electric drives

The electric drives of the ship's cranes receive their power from the ship's switchboard. For this purpose, the ship's 3-phase current is changed by an adjustable converter into either direct current (DC) or an alternating current (AC) with an adjustable frequency.

The control lever operates the converter, which sends current to the motor and releases the brakes. In contrast to the hydraulic engines, the electric motor cannot absorb the forces of a load if the power supply is cut off. In case of a stop command, the brakes are applied instantaneously to overcome this short coming. However, as a result of this, the brakes of an electric winch engine wear faster than the brakes of a hydraulic winch motor.

As in hydraulic drives, excessive lifting, slacking, topping and slewing is prevented by a limit switch.

2.7 Classification of Cranes

Revolving cranes can be categorized by the following types:
- conventional type (section 3)
- low type (section 4)
- heavy lift cranes (section 5)

3. Conventional type crane

The advantage of conventional revolving cranes over low ones is that during topping and slacking, the load remains at the same height. This horizontal level luffing / load travel is achieved by using the high position of the pulley block and the way the runner is reeved through. This ensures that it slacks the same distance as the top of the jib rises. When lowering, the same correction is carried out in reverse.

In the case of double runners, hook blocks are used instead of hooks.

Conventional cranes can differ in the ways that the jib is slacked and topped:
- with a cable (topping lift wire)
- with (two) hydraulic cylinders

3.1 Topping with a steel cable

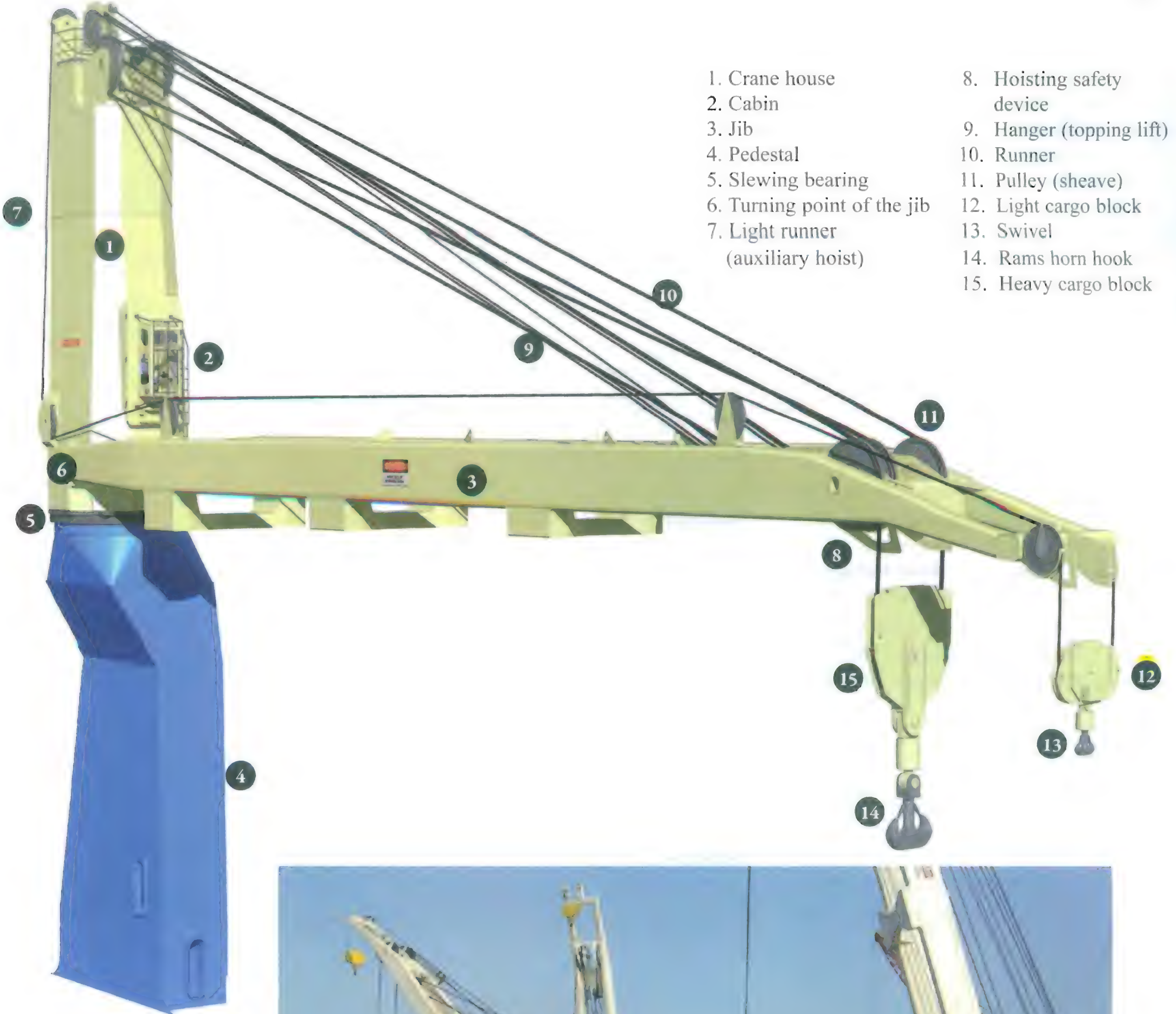
In topping and slacking with a cable, the crane jib is attached to the crane house as low as possible, just above the slewing bearing. A longer distance between the end connection of the topping lift wire and the lower hinge pin of the jib means less force in that wire. Further more, the center of gravity will be lower.

A possible danger in these types of cranes is that in case of a sudden list, a steep crane jib can smash against the crane cabin. This effect is amplified by the forces in the runner. To prevent this, rubber stops are used, but if there is a load hanging from the runner, both the load and the crane-jib can be damaged.

The topping lift wire can be connected to the top of the jib, to a point halfway or a combination of both, preventing vibrations in the jib.

3.2 Topping with hydraulic cylinders

The jib fulcrum is attached higher to the crane house if the crane jib is moved vertically by hydraulic cylinders. This is because the cylinders are attached to the lower part of the jib at one end and to the base of the crane house at the other end. The cylinders are positioned such that they are beside the crane cabin when the jib is completely topped. This means that although the load can touch the crane cabin, it cannot damage the cylinders.
Some typical figures that apply to



Cranes with topping wires

these cranes are:

- maximum lifting capacity of 16-60 tons
- maximum reach 22-34 meters

Using hydraulic cylinders for the topping of the jib has a number of advantages over topping with a steel cable:

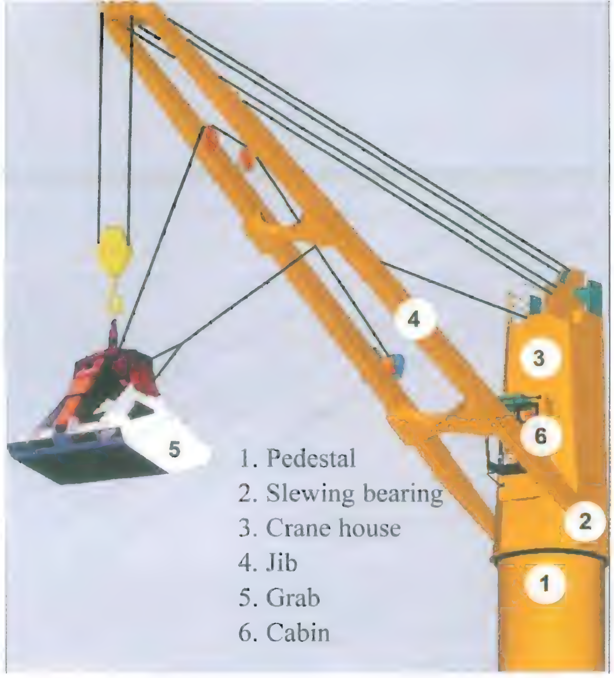
- Slamming of the jib as a result of waves is prevented because double-acting hydraulic cylinders can absorb both pulling and pushing forces.
- Cylinders are easier to maintain than cables. The latter have to be replaced every five years.
- The jib cannot shoot through the top position. This allows cranes with hydraulic cylinders to have a smaller range (2 meters) than cranes with runners (3 meters).

3.3 Crane cabin

The drawing below shows the arrangement of the crane winch, which is driven by an electric-hydraulic motor. An electric motor drives the hydraulic pump which, in turn, supplies oil to the hydraulic lifting and revolving motors.

The oil absorbs the heat that is generated in this process and is subsequently cooled in an oil-cooler by an automated ventilator; then it is pumped back to the hydraulic oil tank.

1. Crane cabin
2. Lever for topping and revolving
3. Lever for lifting
4. Jib
5. Hydraulic motor
6. Oil tank
7. Oil filter
8. Oil cooler
9. Limit switch
10. Drum for topping
11. Drum for hoisting
12. Pulley block

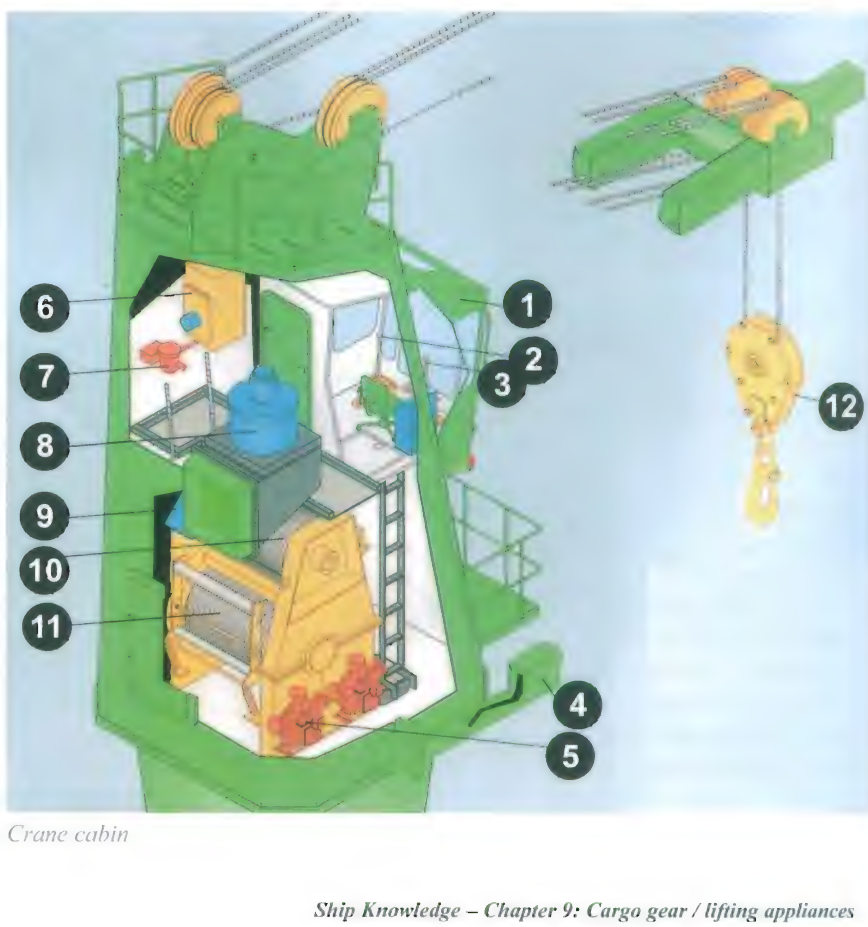


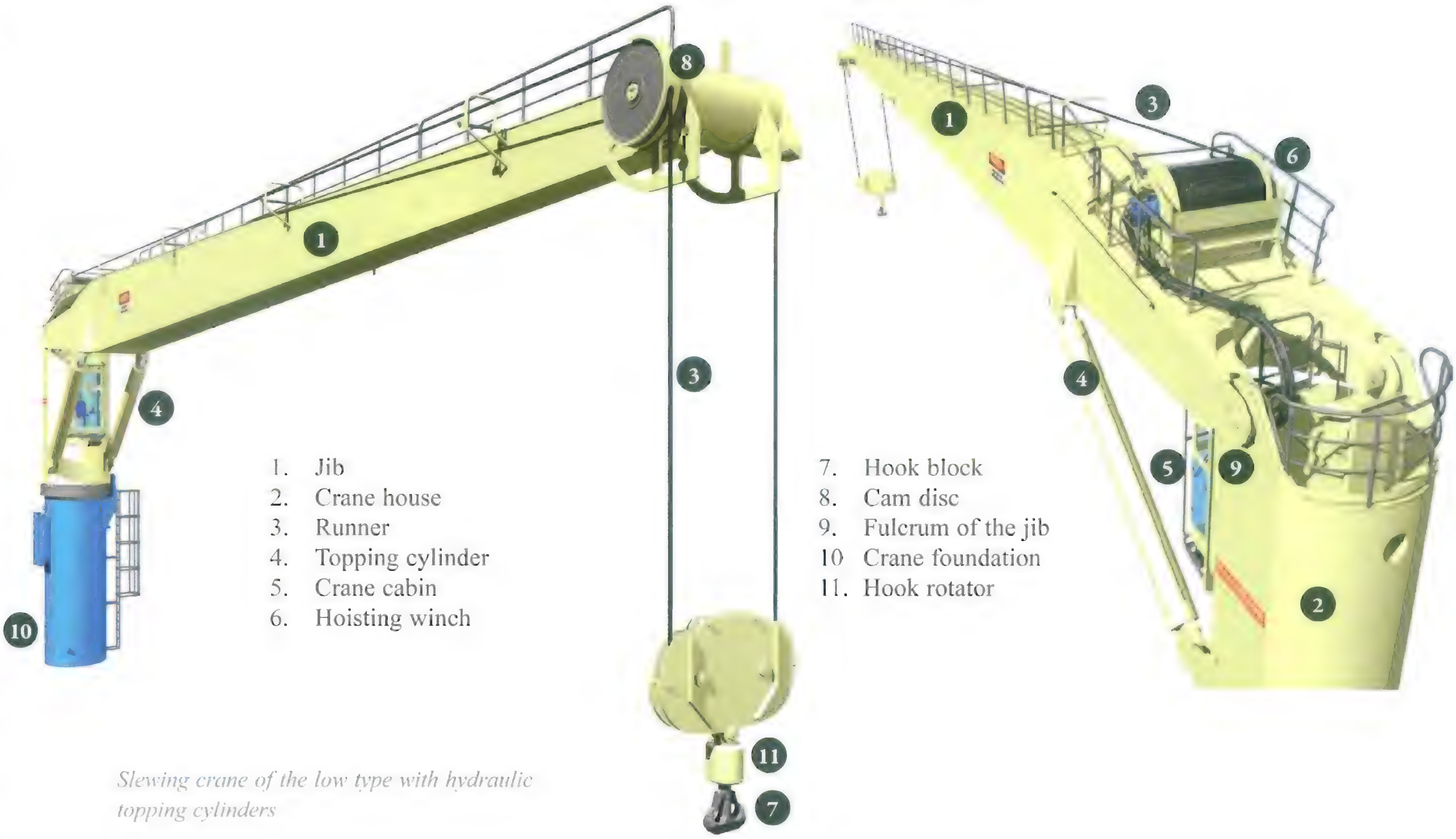
Bulk crane

3.4 Bulk crane

The bulk crane is a unit designed for loading and / or discharging using grabs and logs on standard (handy size, 30,000 tons) bulk carriers. These are usually conventional revolving cranes, up to 20 ton SWL.


Ship with bulk cranes


Crane cabin



Slewing crane of the low type with hydraulic topping cylinders

3.5 Tanker

manifold crane / hose crane

A tanker needs a crane to handle the loading/discharging hose. Often, the hose has to be picked up from the jetty or out of sea in case of a buoy mooring. The hydraulic crane always has a low tubular foundation, with a crane body bolted on through a slewing bearing. The jib is fitted at the top of the body. The jib is supported by a hydraulic ram. The winch is often on top of the jib or on the crane body. There is no crane cabin. A platform with handles, is sufficient. However, often there is a second maneuvring stand at the ship's side. Once the hose is lifted and bolted to the manifold pipe, and hanging in a smooth bend, the crane does not need to be operated during the whole loading or discharge operation. Depending on the ship's size, the SWL ranges from 5 tons for a 5000 ton tanker to 20 tons for a 300,000 ton tanker. The beam of the ship decides if one crane can do the job or if that two are needed beside each other, one on each side. The necessary reach is only 5 to 7 meters outside the ship.

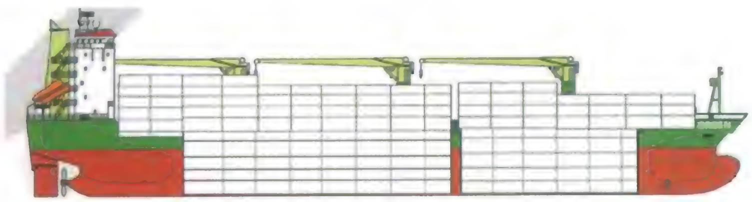
4. Slewing crane of the low type

In cranes of the conventional type the crane houses are 8-15 meters above the slewing bearing. However, in cranes of the low type, this distance is approximately 5 meters. The crane cabin extends just above the fulcrum of the forked jib, which fuses into one box beam jib further away from the crane. The drum of the hoisting winch, which also serves as a pulley, is placed on top of the crane house. The lifting capacity of these cranes can vary between 10 and 150 tons, the range between 12 to 35 meters.

4.1 The crane's construction

The figures above show one of many versions of the low type cranes. A peculiarity of this crane is that the horizontal position is merely used to "park" the crane in the boom cradle: the boom rest. When operating, the crane should remain topped at least 15°, as indicated by the minimum and maximum range. All revolving cranes give the load a certain freedom of rotation. The **runner** itself, however, also has the tendency to entwine when being loaded or unloaded. For this reason, the hook is always connected to the runner via a swivel bearing, allowing the two parts to rotate independently.
When a double cargo runner is used, the hook block must not rotate relative to the crane jib because this will cause the two parts of the runner to get entangled.

A special **electric-hydraulic hook rotator** can be used to prevent this and to prevent undesired rotation of the load.
The crane jib has a cable reel that slacks and hoists the power cable via a number of guide sheaves, ensuring that it never hangs too loosely or too tightly and that it follows the cargo hook precisely. This cable reel is controlled by the crane driver with the same (right) lever that the driver uses to control the hoisting winch.



More containers fit beneath the jib without obscuring the view

4.2 Advantages of the low crane

- The jib of a low crane is much higher compared to a conventional crane where the top of the crane house is at the same height. This way the crane can still operate, even if there are many containers stacked on top of each other.
  The low crane has a lower weight and a lower center of gravity compared to a conventional crane with the slewing bearing at the same height. This offers more stability and increases cargo capacity.
- If containers are stacked at the same height, the low crane gives the bridge greater visibility.

5. Cranes for heavy cargo

The cargoes to be transported by ship are continuously increasing in weight. The shipping industry therefore builds ships for heavy cargo, where every new generation of ships gets cranes with a higher capacity than the previous generation.

The cargoes this type of specialized ships are built for, can be complete installations for the petro chemical industry, or power stations and suchlike, as long as there are heavy components amongst the total package.
Nowadays, cranes with a lifting capacity of 150 tons or more, are called 'cranes for heavy cargo'. The lifting capacity can be as high as 800 tons.

There are two basic types of heavy cargo cranes:
- conventional cranes
- mast cranes.

The **conventional crane** has a crane house, mounted on and revolving through a slewing roller bearing, with a connected crane jib. The slewing bearing is bolted to a pedestal and has to take the full tilting moment of the crane plus cargo. This bearing usually is a 3-row roller bearing. This type of crane has the advantage that the winches are located inside the crane house, and slewing can be carried out unobstructed.

The **mast crane** is installed around a mast, welded to the ship's construction. At the lower part of the mast a platform is mounted which can rotate around the mast. On this platform the jib, or derrick is mounted. On top of the mast is a free-turning swivel head, with sheaves for the hanger and runner wires. The winches are installed inside the mast, inside the pedestal of the mast or even below deck.

1. Mast
2. Jib
3. Topping lift and running part of the hoisting rope
4. Cargo hook
5. Hook of auxiliary hoist
6. Slewing bearing
7. Mast foundation / pedestal
8. Top slewing unit

A heavy-lift ship with a heavy piece of cargo , working in tandem

The hanger and runner wire go through the mast to the top swivel. This arrangement restricts slewing ability, normally to + or - 270°.

Conventional cranes are built to a maximum of 400 tons, restricted in by the cost of the slewing bearing. Higher lifting capacity is not economical and is technically too difficult. For weights above 400 tons the mast crane is usually used.
These cargoes impact the ship's construction. The double bottom and the tank top have to be adapted to a large number of tons per m^2.
Stability requires anti-heeling tanks, with high capacity pumps to prevent listing of the ship during cargo lifting from outside the ship. Usually side tanks are used for this purpose.
To increase the stability, side pontoons, which can be emptied or filled with water, attached to the ship's side are often used, enlarging the moment of inertia of the waterline.

The cranes are often used in tandem to load a heavy part. The load control is therefore, computerized, and both crane drivers have information on display about both cranes. Reach and load are maximized via the load / moment curve calculated for each individual crane, which are not to be exceeded.

For heavy cargoes, the ship is provided with special tools - heavy slings, shackles, spreader beams, etc. Suitable lashing gear also has to be provided. All these tools are load-tested, marked and certified.

5.1 Hoisting diagram

The capacity of a crane depends on the range and maximum load of all parts of the crane, together as well as apart. The right side of the graph shows the importance of the range. The heeling angle is also clearly visible.

Heavy-lift ship with hatch covers fitted as portable tanks to enlarge the waterline area and thus the stability

5.2 Stabilizing pontoons

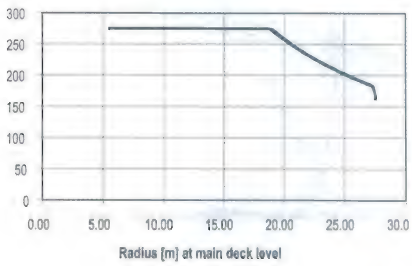
Stabilizing pontoons are employed when the heeling tanks fail to reduce the list to an angle of less than 3°. The pontoons are necessary when the GM gets smaller than 1 meter. They are rigidly attached to the sides of the ship at a distance of 0.5 meters in such a way that the ship and pontoon essentially become one.

A pontoon consists of tanks that can be filled and emptied independently.

The pontoon increases the GM of the ship in the picture by 0.4-0.8 meters. It can transfer both downward and upward forces. After use, the pontoons are emptied and lifted back on board.

Stabilising pontoon for increased waterline area. in use.

Spreader beam



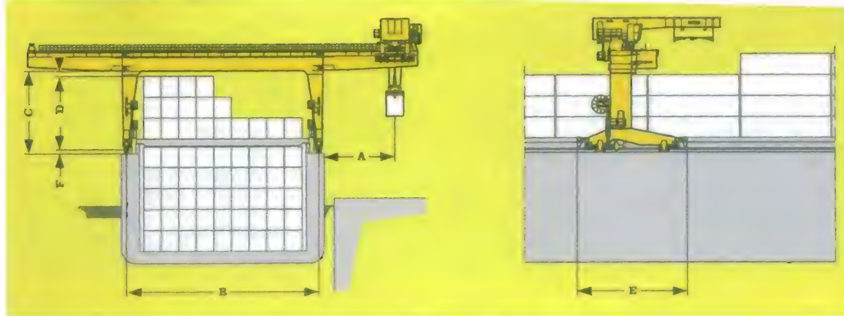
Hoisting diagram for a derrick

Jib angle	83°	49°	27°	13°	0°
Lift capacity	275 t	275 t	203 t	186 t	162 t
Range	5.0 m	18.8 m	25.0 m	27.0 m	27.5 m

6 Gantry cranes

Gantry cranes are deck cranes that can travel over the cargo, along the ship in longitudinal direction. Many different types of cranes can be attached to the gantry. Ships without their own cargo gear often use a simple gantry crane as a hatch cradle.
Gantry cranes specifically for the handling of cargo can be divided into three main types:
- gantry cranes with a revolving crane on top
- gantry cranes with a moveable cable trolley with jib
- gantry cranes with a double portal and cable trolley without a jib

Gantry cranes are always sensitive to trim; 2° often is the maximum. Cranes that have a cable trolley are even more sensitive and in this case a list of 2° is the maximum.


Gantry crane with a cable trolley and a fixed jib, front and side view


U-gantry with trolley on a container-ship


Multipurpose ship with hatch cradle

If there is a revolving crane on top this maximum may be a bit higher, but it will never be more than 5°.
The **four-point suspension** of the hoist gives a gantry crane excellent load control. This ensures that the load stays in line so that it can be deposited at the right location.

A disadvantage of gantry cranes is their massive weight that shifts the center of gravity to a higher point. This reduces stability and carrying capacity. An advantage is that the ship needs very little strengthening; only the guide rails on deck need a strong foundation.

A characteristic of gantry cranes is the large **reel** on the side for the feeder cable.

The portal uses train wheels to travel over the guide rails. The pinions mesh into a toothed rack, attached to the longitudinal beam, which is usually the foundation for the rails. Clamps on the sets of wheels fit around the rails without actually touching them in order to prevent the gantry from tipping over. During the voyage, heavy gantry cranes are lifted free from the rails by hydraulic jacks, in order not to damage the wheels (ball-bearings) and rails by the ship's vibrations.

7 U-gantry with a cable trolley without a fixed jib

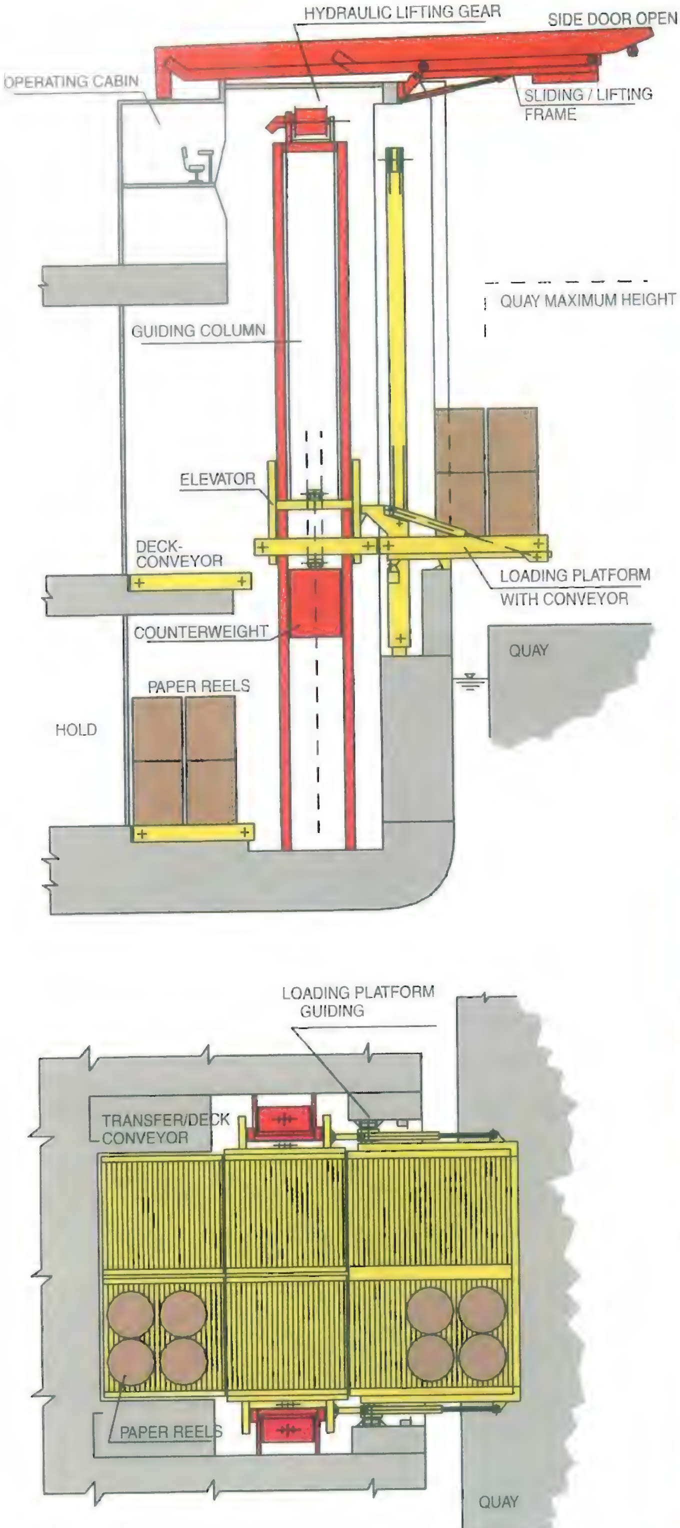
The crane's forces are distributed more equally in gantry cranes with two beams and a cable trolley without a jib than in a gantry crane with a fixed or rotating jib; there are more torsional forces in the latter. This allows the structure to be only slightly heavier than structures with only one beam. However, the crane cabin should be placed higher than in the other two types of gantry cranes because the load always remains some distance below it.

This type of gantry crane is best used for moving:
- containers
- parcels of timber or paper
- rolls of thin steel
- other bundled cargo

8 Side loaders

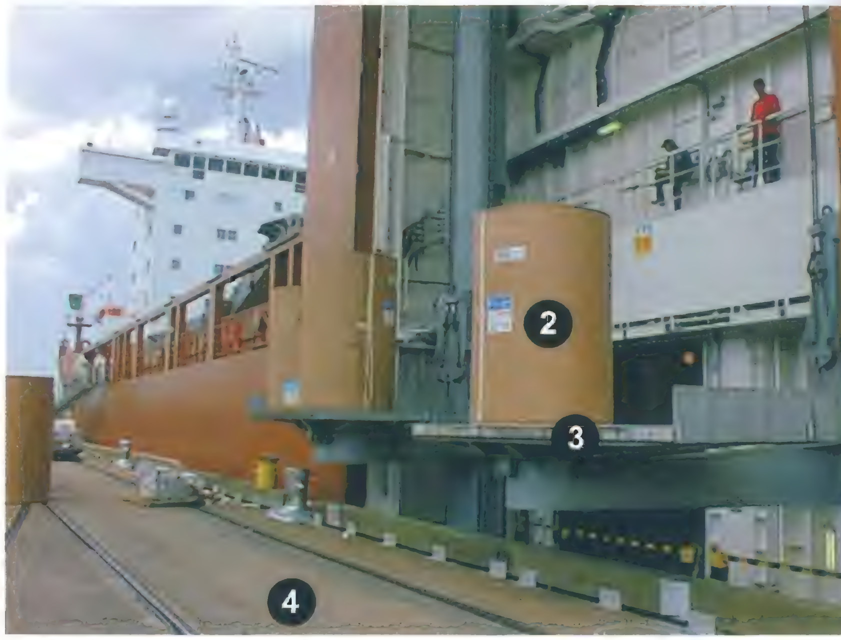
Side loader systems are used for the transshipment of small cargo units like pallets, rolls of paper and general cargo. The system comprises one or more doors in the side of the ship, and one or more elevators situated behind these doors to transport the cargo from the ramp, at quay level, to the holds and vice versa.

The advantages are:
- it has minimum impact on the ship's stability because it adds almost no weight
- furthermore, the ramp lies low
- a high transfer capacity - the cargo does not have to be transported over unnecessary distances, minimizing the waiting period
- if the route over the quay to the ship is covered, loading and discharge of delicate cargo (paper rolls) can continue during rain or snow



Side and top view of an elevator system

Ship with three side doors



Paper rolls on the elevator. The cargo is transported by the lift to the

A fork lift picks up paper rolls to convey them to the holds

The disadvantages are:

- the doors in the side of the ship reduce the longitudinal strength, which has to be compensated for applying thicker plates around the hole in the ship's side
- the elevators reduce the available cargo volume
- the elevators are unsuitable for heavy loads
- there is a maximum size for the cargo to fit the dimensions of the elevators

Some characteristics of side load systems

- the maximum work load (of the elevator) is 8-20 tons
- the lifting speed of the elevator is 0.33-0.66 m/s (20-40 meters/min.)

1. Opened side door
2. Cargo (paper rolls)
3. Elevator
4. Quay
5. Tweendeck

Side door with special loading and discharge gear for paper rolls

9 Ramps

Ro-Ro vessels are ships where the cargo is brought on board via wheels and ramps. Loading and discharging can take place quickly due to the speedy and mainly horizontal transport.

An advantage of this is that the ship is independent from the shore facilities. In general, ramps have sufficient length to be used both in high and low tides. Opening and closing is done with a winch or hydraulic cylinders. Closing and securing is done using hydraulic sequence locking systems. When the ramp is in closed position, the locking wedges, bars, hooks, etc, are operated by hydraulic cylinders.

The most important types of ramps are:
- straight ramps, extending straight from the forward and aft ends or from the side
- quarter ramps, having an angle of 45° relative to the centerline.
- slewing ramps, with an angle between +45° and -45° relative to the centerline.

Driving from the loading deck to the other decks also proceeds via internal ramps.

These include:
- fixed ramps
- adjustable ramps
- car decks that also serve as ramps

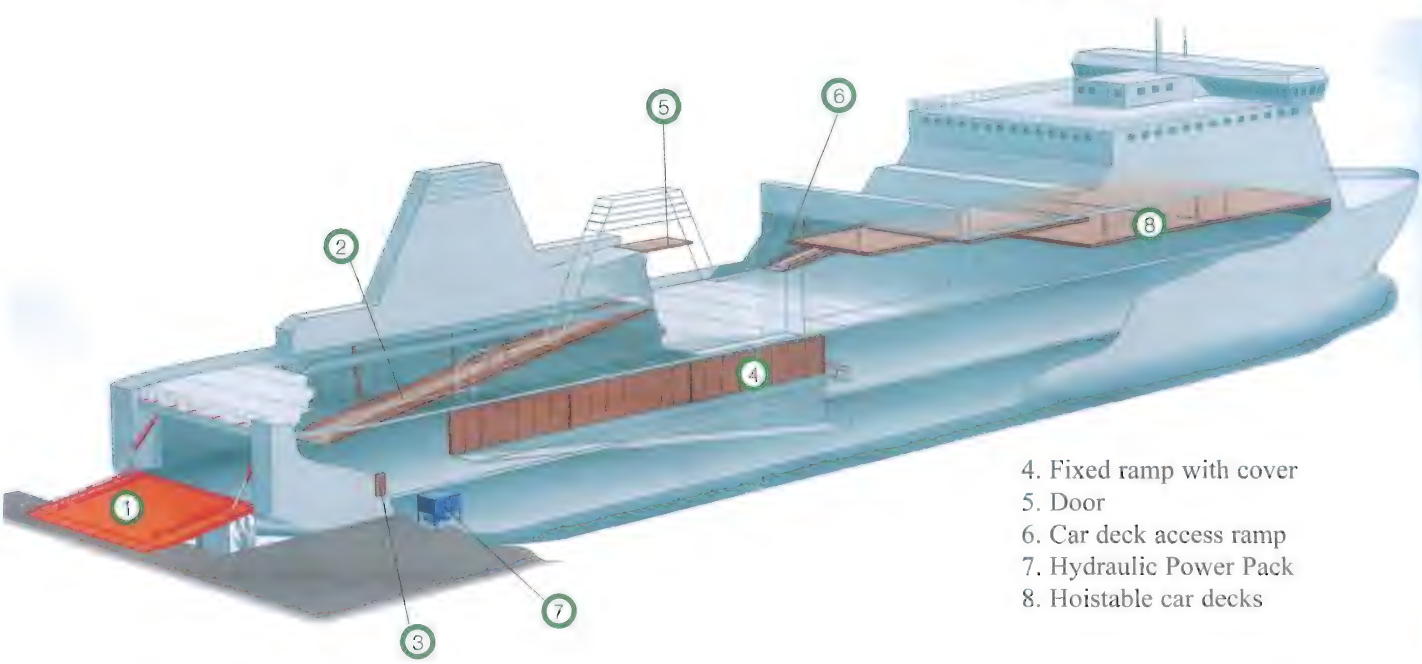
9.1 Ramps between ship and shore

– **Straight ramps**

The use of straight ramps means that the ships sometimes depend on a specially designed, sloped quay, with a landing area for the ramp. If loading and discharge are done via the fore or the aft ship, the full length of the ship has to fit in the berthing place. However, this is not necessary if the straight ramp is lowered from the side of the ship.

– **Straight ramp in the fore ship**

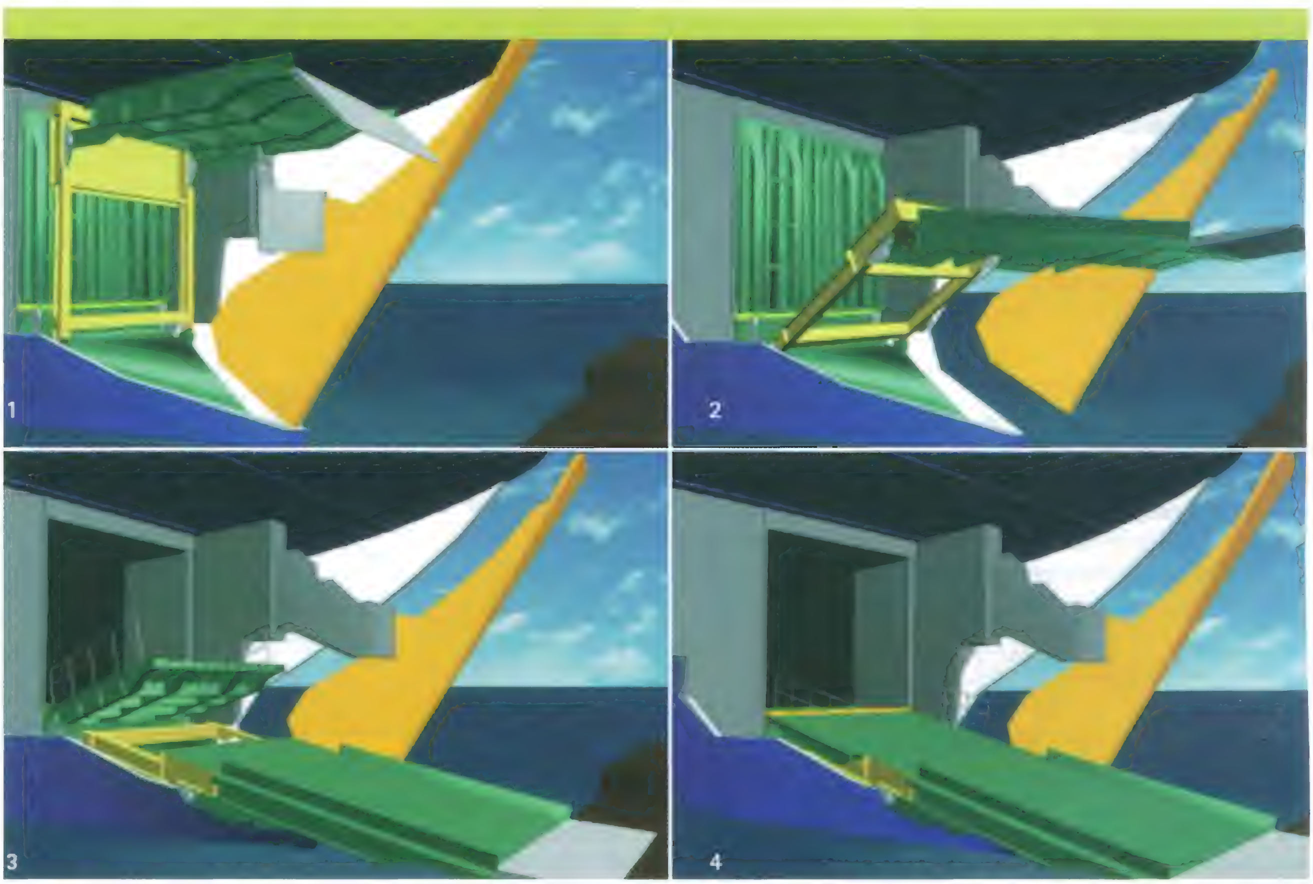
A straight ramp forward, is normally combined with a watertight door, behind bow doors or sometimes a bow visor. The bow doors have a very complicated shape as this is part of the profile of the ship's bow. The inside of these doors have a flat edge with a rubber seal to make the door watertight. The **bow doors/visor** absorb the forces of the waves, and are therefore subject to stringent requirements for strength, locking system, seals and security. Rules stipulate that the bow ramp and the watertight door, positioned at the collision bulkhead, must be separated from each other. This is normally accomplished in one of the two following ways.



Ro-Ro vessel:
1. Straight stern ramp/door
2. Hoistable ramp
3. Shell door
4. Fixed ramp with cover
5. Door
6. Car deck access ramp
7. Hydraulic Power Pack
8. Hoistable car decks

Straight ramps in the fore ship

1. Outer bow door = ships shell
2. Watertight door at collision bulkhead
3. Lower ramp,
4. Inner ramps to upper car deck



Principle of two-part ramp


Straight ramp in the aft ship


Straight ramp in the side


Inboard ramp


Ship with quarter ramp in dry dock

1. With a **folding frame bow ramp** arrangement the collision bulkhead door can be completely separated from the rest of the ramp. This implies that no part connected to the door will extend forward of the correct position for the collision bulkhead. A steel frame is positioned forward of the collision bulkhead door and controls the folding movement through hinge connections with the outer part of the ramp. In the fully open position the frame, together with the outer section, forms the load carrying structure (see figures and photos).

2. A normal bow ramp/door arrangement is fitted behind the bow doors/visor. Behind this ramp, at the position of the collision bulkhead, another set of doors is fitted.

– **Straight ramp in the aft ship**

The aft ship can suffice with just one watertight door, which, if it is flat, is used as a ramp. The picture on the right illustrates this. The closed ramp protrudes above the aft ship.

– **Straight ramp in the side**

Straight ramps can also be located on the side and are comparable to the straight ramps in the stern and to the side loaders discussed earlier. The ship designer tries to make the side ramp in such a manner that, when closed, it forms a seamless whole with the ship's skin. There are also stringent requirements for locking, sealing and safety measures for these types of ramps.

Hoistable car deck

1. Hoistable car deck
2. Hangers with hinges
3. Hoisting wire
4. Ramp
5. Deck

– **Quarter ramps**
A quarter ramp makes an angle of approximately 45° with the ship's centerline. This limits the orientations of the ship in berthing to the side where ramp is located.

9.2 Inboard ramps

- **Fixed inboard ramp**
The figure on page 208 shows a ship with a fixed ramp that leads to the lower hold. Economically a disadvantage, as nothing can be stored beneath the ramp.

Hoistable car decks
A hoistable car deck is shown in the figure lower left. These can be used as tweendecks, allowing two layers of cars to be transported above each other.
When the tweendeck is full, the ramp, complete with cars, is hoisted to the tweendeck position. The space below the movable car deck can be loaded when the ramp has been hoisted.

- **Hoistable Inboard Ramps**
Between decks, hoistable ramps are used, which are closed, by lifting the ramp, thus closing the upper deck or the freeboard deck. This has implications for tightness, strength, certification.
This type of ramp can be very long, depending on angle when lowered and height of the cargo space below.

– **Cargo lifts**
Trailer lifts provide the only solution to the problem of transferring trailers between deck levels in areas of Ro-Ro ships where longitudinal space is limited.
The trailer lifts are available in a wide variety of configurations to suit individual applications.
The layout of the installation can be arranged to enable the lift platform to act as a watertight hatch cover when secured in its upper level position.

– **Elevators**
Personnel elevators need to be tested and certified yearly by a recognized company.

10 Registers and certificates

Every ship with cargo-gear has to be provided with documentation:
– **Register of Ship's Cargo Gear and Lifting Appliances,** accompanied with the relevant testing certificate:
  • Certificate of Test and Examination of Winches, Derricks, and Accessory Gear
  • Certificate of Test and Examination of Cranes or Hoists and their Accessory Gear
  • Certificate of Examination and Test of Wire Rope (for each rope!)

Cranes, used in the Offshore Industry, are subject to more stringent regulations in connection with use at an Offshore Unit, ship or platform or at sea, and are subject to the unit's movements. These cranes are called Offshore Cranes.

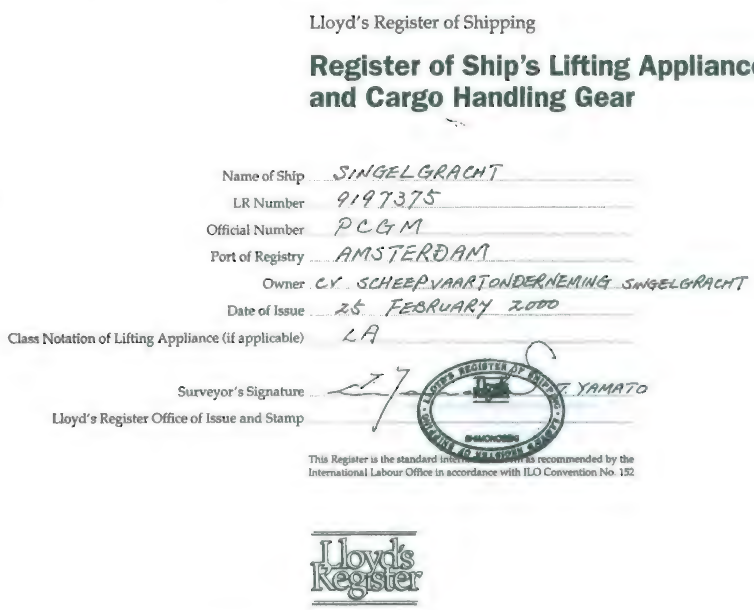
Repairs to any cargo gear item have to be done under supervision of Class or flagstate, and generally, re-testing and re-certification have to be carried out.

Movable or hoistable ramps between decks are in some cases also cargo space. When a lorry is placed on the ramp before it is hoisted, ramp is cargo gear, and subject to the normal cargo gear inspections and testing.


Quarter ramp


Slewing ramp

In that case the ramp needs to be registered in the cargo gear book. Wires and locking devices need to be tested by ship's staff regularly, as per ISM requirements. If this is a ramp between a lower deck and the freeboard deck, the ramp is a watertight closing and also subject to the regulations for loadline, with the inspections and tests for weather-tightness.


Lloyd's Register of Shipping

Register of Ship's Lifting Appliances and Cargo Handling Gear

Name of Ship SINGELGRACHT
LR Number 9197375
Official Number PCGM
Port of Registry AMSTERDAM
Owner CV SCHEEPVAARTONDERNEMING SINGELGRACHT
Date of Issue 25 FEBRUARY 2000
Class Notation of Lifting Appliance (if applicable) LA
Surveyor's Signature T. YAMATO
Lloyd's Register Office of Issue and Stamp

This Register is the standard in ... as recommended by the International Labour Office in accordance with ILO Convention No. 152

Lloyd's Register

First page of cargo gear book

PART I THOROUGH EXAMINATION OF LIFTING APPLIANCES

Note 1
Except for initial examinations, if all the Lifting Appliances are thoroughly examined on the same date it will be sufficient to enter in column 1 'All Lifting Appliances'. If not, or if an initial examination is conducted then the Lifting Appliances which have been thoroughly examined on the dates stated must be clearly indicated.

Note 2
The thorough examinations to be indicated in column 3 include:
Initial
12-monthly
Five-yearly
Repair/damage
Other thorough examinations

Situation and description of Lifting Appliances with distinguishing numbers or marks, if any) which have been thoroughly examined (see Note 1).	2 Certificate Nos. Form: L.A.2 L.A.2U	3 Examination performed (see Note 2)	4 I certify that on the date to which I have appended by signature, the Lifting Appliances shown in column 1 were thoroughly examined and no defects affecting their safe working condition were found other than those shown in column 5 (Date, stamp and signature)	5 Remarks (to be dated and
Side Loading System Nos. 1 through 5 Cargo Lifts	SMK 9840054/1	Initial	T. Yamato 25/02/00	
Deck Cranes Nos. 1 through 3	SMK 9840054/3	Initial	T. Yamato 25/02/00	

Page in cargo book with the applicable cargo gear for which the book is issued.

1 Situation and description of lifting appliances (with distinguishing numbers or marks, if any) which have been tested and thoroughly examined	2 Angle to the horizontal or radius at which test load applied	3 Test load (tonnes)	4 Safe working load (SWL) at angle or radius shown in column 2 (tonnes)
Deck Cranes			
No. 1 deck crane at No. 1 cargo hold starboard	14.0 metres	132.0	120.0
	18.6 metres	99.0	90.0
	30.0 metres	55.0	50.0
No. 2 deck crane at No.2 cargo hold starboard	14.0 metres	132.0	120.0
	18.6 metres	99.0	90.0
	30.0 metres	55.0	50.0
No.3 deck crane at No.3 cargo hold starboard	14.0 metres	132.0	120.0
	18.6 metres	99.0	90.0
	30.0 metres	58.3	53.0

I certify that on the date to which I have appended my signature, the gear shown in column 1 was tested and thoroughly examined and no defects or permanent deformation were found; and that the safe working load is as shown.

Date 25 February 2000	Remarks The equipment have been assigned the Society's LA Notation.
Port Shimonoseki	
Signature - Surveyor to Lloyd's Register of Shipping T. Yamato	

This certificate is the standard international form as recommended by the International Labour Office in accordance with ILO Convention No. 152.

FORM 1380 (L.A.2) (04/98) 1/2 Lloyd's Register of Shipping, registered office: 71 Fenchurch Street, London EC3M 4BS

Test certificate of deck cranes

11 Load testing equipment.

All equipment intended to be used in lifting gear needs to be certified. Regulations for lifting equipment and testing are international. This means that material qualities are checked, workmanship is judged and that a load test has to be carried out under the supervision of a regulating body. For ships this is normally the Classification Bureau.

All the items in hoisting gear must be covered by a certificate, stating an identification and test. The load test is carried out to guarantee a Safe Working Load (SWL) or the Working Load Limit (WLL).

A crane as a complete unit is tested by lifting a weight, and carrying out the normal movements such as hoisting, lowering, slewing and topping. When power to the crane is interrupted, the brake has to hold the load.
The weight for testing is heavier than the WLL. For the smallest cranes this means 25% overweight, for the largest, 5 tons more than the SWL.

Individual small items belonging to the crane, such as blocks, hooks, shackles, etc. are normally tested at a load in accordance with ILO and the Classification:
- single sheave blocks at 4 times the SWL
- multi sheave blocks below SWL 25 ton, at 2 x SWL
- multi sheave blocks between SWL 25 and 160 ton at (0.933 x SWL) + 27 ton
- multi sheave blocks over 160 ton, at 1.1 x SWL
- hooks, shackles, chains, rings below SWL 25 ton at 2 x SWL
- hooks, shackles, chains, rings above SWL 25 ton at (1.22 x SWL) + 20 ton.

Test weights can be steel weights with a known mass; the modern variant is a **water bag**, which can be filled with water till the required mass is reached. A certified load cell indicates the weight. Water bags are available up to 35 tons.

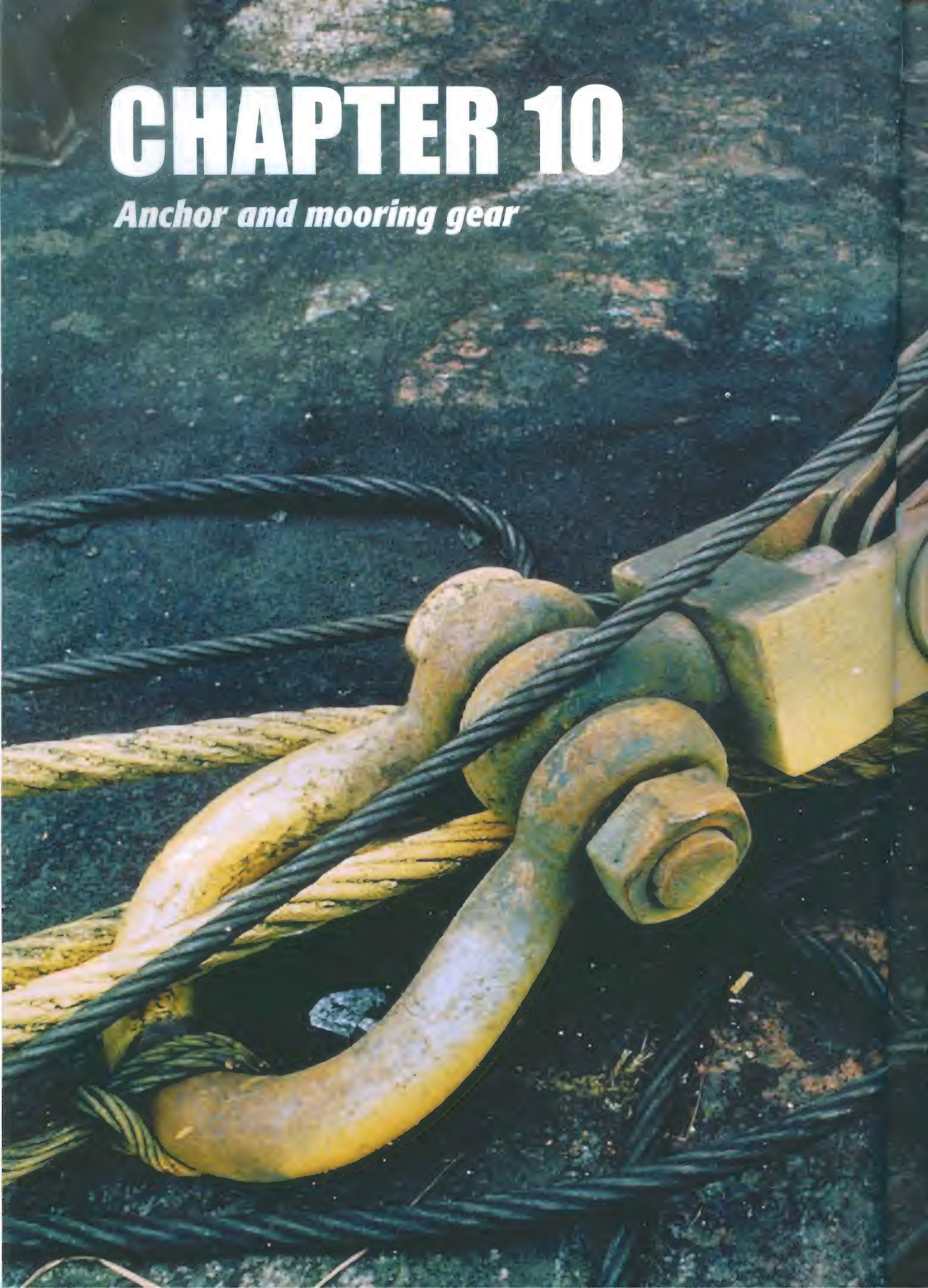
Testing the crane using water bags

Testing with waterbags has a maximum.
For bigger loads special ly constructed pontoons are used.

Testing lifeboat davits using water bags

CHAPTER 10

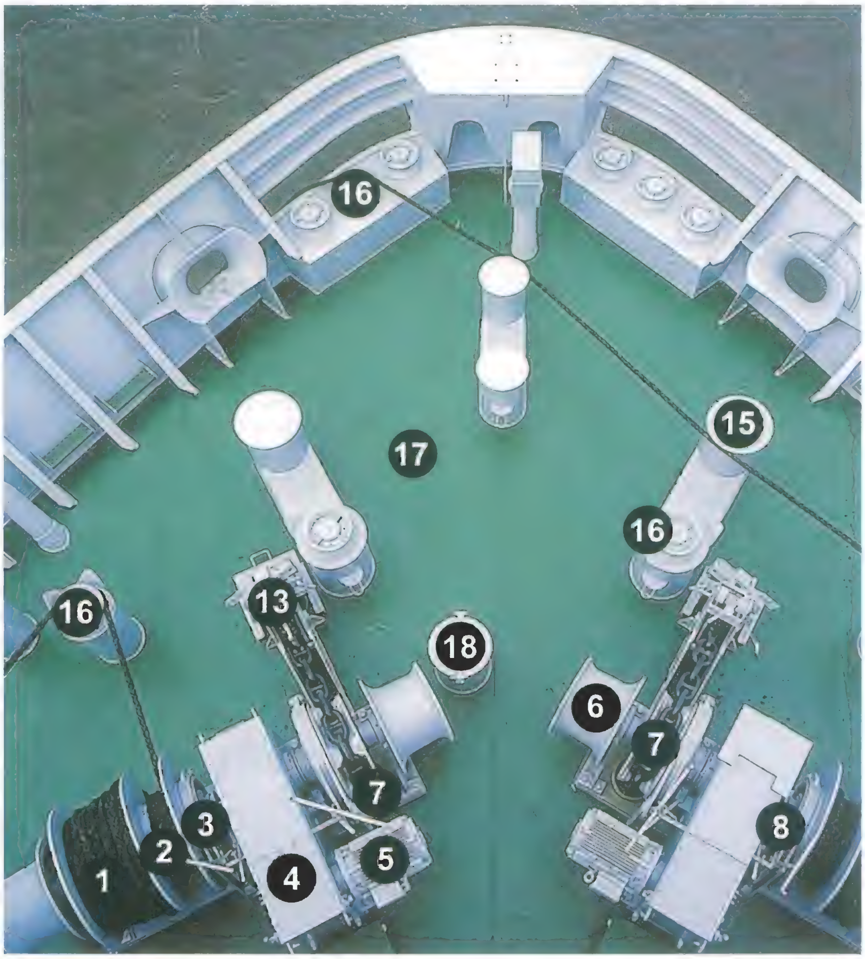
Anchor and mooring gear

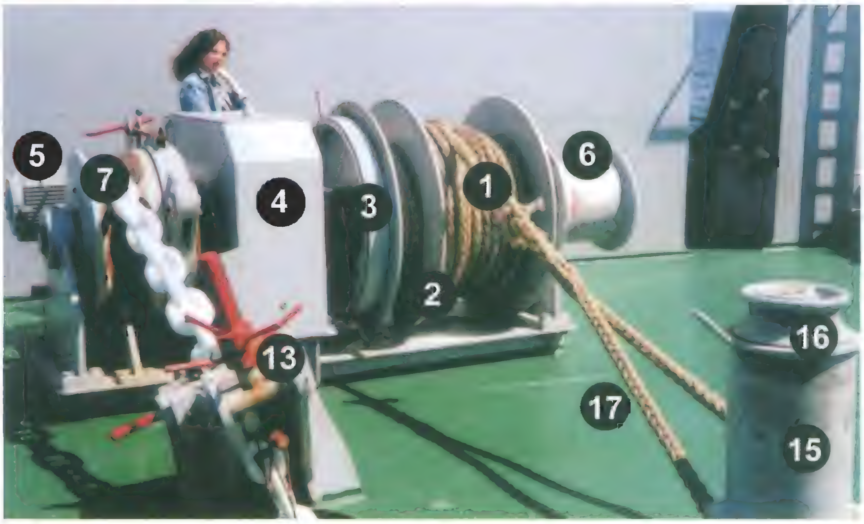


SHIP KNOWLEDGE

Covering Ship Design, Construction and Operation

1 Overview of Anchor and Mooring Gear

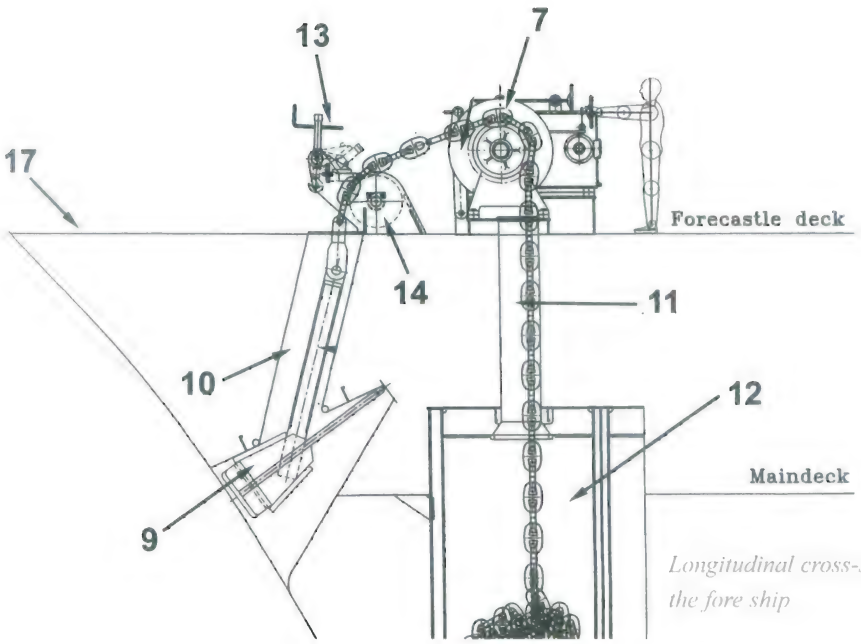




Anchor windlass on general purpose ship with mooring drum and warping head

1. Storage part of the mooring drum
2. Pulling section of the drum (working part)
3. Brake band
4. Gear box
5. Electro-hydraulic motor
6. Warping head
7. Chain in the gypsy wheel
8. Dog clutch
9. Anchor
10. Hawse pipe
11. Spurling pipe
12. Chain locker
13. Chain stopper with security device
14. Guide roller
15. Bollard
16. Guide roller
17. Deck
18. Hatch to chain locker

(see also next page)



Longitudinal cross-section of the fore ship

> *The* ***equipment number*** *can be calculated with the equation:*
>
> $(\Delta^{2/3} + 2HB + 0.1A)$
>
> Δ = *displacement (weight of the ship) this term indicates the influence of displacement and the currents on the ship*
>
> HB = *width and height - determines the influence of frontal winds (m^2)*
>
> A = *the lateral surface of the ship (above the water), which determines the influence of side winds (m^2)*

2. Anchor equipment

2.1 Purpose

The purpose of the anchor gear (or ground tackle) is to fix the position of a ship in shallow water by using the sea-bed. Reasons for doing so can be:

- the ship has to wait until a berth becomes available
- to load or discharge cargo when a port does not have a berth for the ship, either temporarily or permanently
- to help with maneuvring if the ship does not have a bow thruster and/or no tugboats are available
- in emergency cases to avoid grounding

2.2 Legal requirements for the anchor and mooring gear

Each bow anchor needs to be provided with a certificate, issued by Class, based on type, materials used, weighing and testing.

The same is applicable to chain cables. A certificate for the anchor and mooring equipment is only issued after all the requirements of the Classification Society are met. The original certificate has to be on board. The table below indicates equipment numbers used to determine the minimum weights and dimensions of the anchors, chains, ropes, etc. The equipment number can be found on the Midship Section drawing.

EQUIPMENT NUMBER		EQUIPMENT LETTER				STOCKLESS BOWER ANCHORS			STUDLINK CHAINCABLES		
							WEIGHT PER ANCHOR			DIAMETER	
EXCEED-ING	NOT EXCEED-ING	LRS	ABS	DNV	GL	NUMBER OF ANCHORS	CONV. KGS.	HHP KGS.	TOTAL LENGTH METERS	SPEC. STEEL (GRADE U2) MM	EX.SP. STEEL (GRADE U3) MM
550	600	P	U16	p	117	3	1740	1305	440	36	32
600	660	Q	U17	q	118	3	1920	1440	440	38	34
660	720	R	U18	r	119	3	2100	1575	440	40	36
720	780	S	U19	s	120	3	2280	1710	467.5	42	36
780	840	T	U20	t	121	3	2460	1845	467.5	44	38
840	910	U	U21	u	122	3	2640	1980	467.5	46	40
910	980	V	U22	v	123	3	2850	2140	495	48	42
980	1060	W	U23	w	124	3	3060	2295	495	50	44
1060	1140	X	U24	x	125	3	3300	2475	495	50	46
1140	1220	Y	U25	y	126	3	3540	2655	522.5	52	46
1220	1300	Z	U26	z	127	3	3780	2835	522.5	54	48
1300	1390	A†	U27	A	128	3	4050	3040	522.5	56	50
1390	1480	B†	U28	B	129	3	4320	3240	550	58	50
1480	1570	C†	U29	C	130	3	4590	3445	550	60	52
1570	1670	D†	U30	D	131	3	4890	3670	550	62	54

Pool anchor (HHP) Type HG "Pool N" anchor

Hall anchor (conventional anchor)

1. Crown / shackle
2. Shank
3. Flukes
4. Crown pin
5. Crown plate
6. Anchor chain with swivel

2.3 Anchors

Anchors are the **final safety resource** of a ship. From ancient times, the men using them had a stone on a sling to keep the boat in position. Later developments show combinations with wood, ending in the stock anchor (fisherman's anchor) with wooden stock. When propulsion or steering fails, the seafarer has to rely on his anchoring equipment. It is therefore of utmost importance that this equipment is in good condition. A regular check of the condition of the anchor itself, the crown, anchor shackle, the chain cable, windlass, brake band and anchor securing arrangements is the responsibility of the master.

In general, ships have two bow anchors and sometimes a stern anchor. There are two bow anchors for safety. Under normal circumstances one anchor is sufficient, but under severe weather conditions or in strong current both anchors may be needed. Also, if one anchor fails, the second anchor is a back-up. Normally a ship is not allowed to sail from any port when one anchor has been lost.

The Classification Bureau may allow departure under the condition that replacement is carried out at the earliest opportunity and that the vessel takes additional tug assistance leaving and entering port.

The stern anchor is used to prevent ships (coastal trade liners, for example) from rotating due to tidal changes in a river current.

Anchors can be:

Conventional anchors
HHP anchors (high holding power)
SHHP anchors (super high holding power)

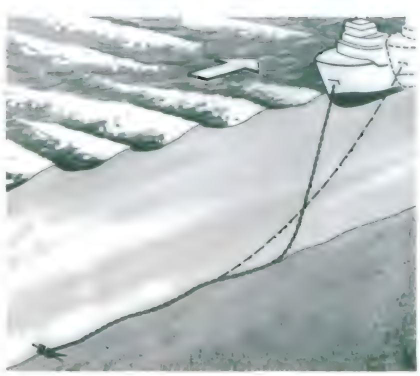
Common conventional anchor types are Spek, Hall, Union and Baldt.

Spek anchors have the advantage of being **fully balanced.**

A fully balanced anchor has the following advantages:

- an anchor recess that completely envelops the anchor, can be used the shell cannot be easily damaged during heaving when the anchor flukes leave the water vertically

Accepted HHP anchors are AC14, Pool and Danforth. CQR and Plow-type anchors are only used on small craft. Various copies of accepted types are made all over the world.



The total holding force is supplied by the anchor and the weight of the chain. The dashed lines in the drawing show that it is not dangerous if a ship floats away for a certain distance (a ship's length) from the original anchor position.

A fully balanced anchor means that when the anchor is being weighed, lifted from the seabed into the hawse pipe with the flukes vertical, the weight of the head serves as being a counterweight. Such an anchor is never fouled, i.e. with the flukes pointing into the ship's shell.

The conventional type is still used a lot and serves as a standard for newer types of anchors (see table).

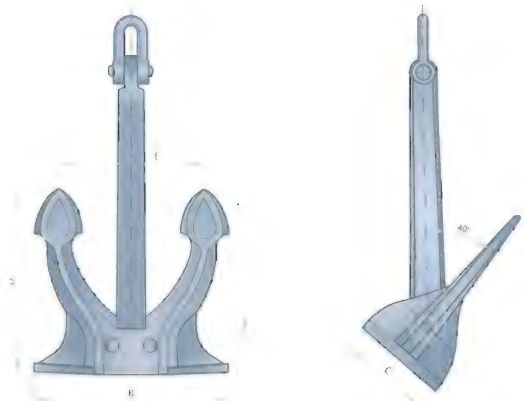
Conventional anchors are always cast. Newer types, such as Pool, can also consist of plates (or other components) that are welded together. If the flukes are hollow, they tend to be more resistant towards bending forces.

The crown plate ensures that the flukes of the anchor penetrate the sea floor. In certain types of anchors, flukes prevent the anchor from burying itself too deeply in the sea bottom.

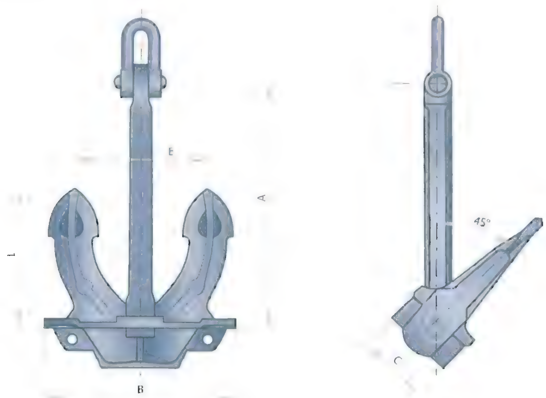
The navy uses a specially developed HHP anchor with an open crown plate (bottom plate). The advantage of this type of anchor is that it digs into the bottom more rapidly.

HHP-anchor with an open crown plate

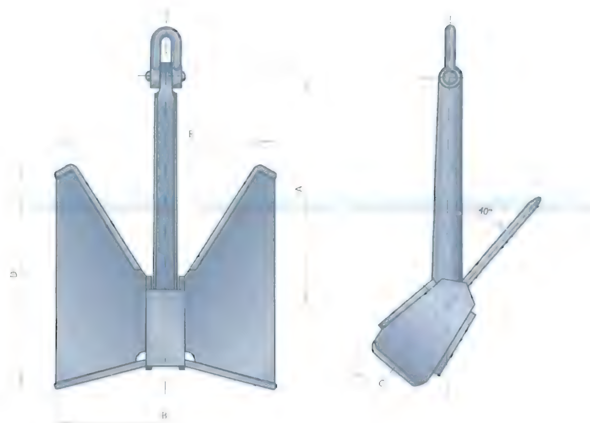
Stevin anchors on a deck of an Anchor handling tug supplier (AHTS)



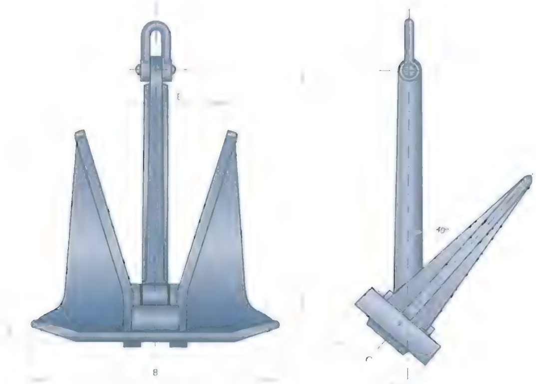
Spek anchor



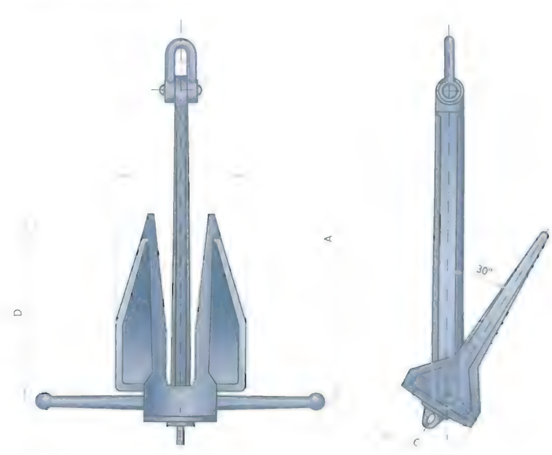
Hall anchor



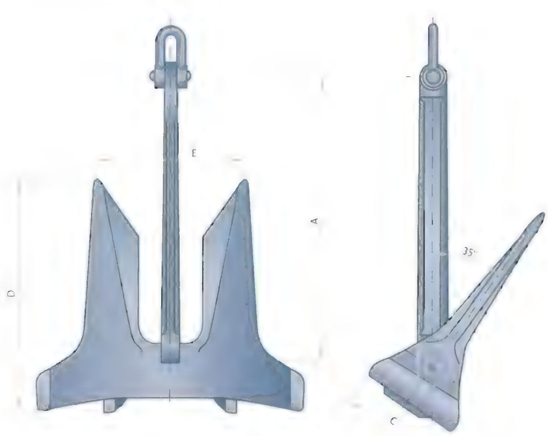
Pool TW anchor



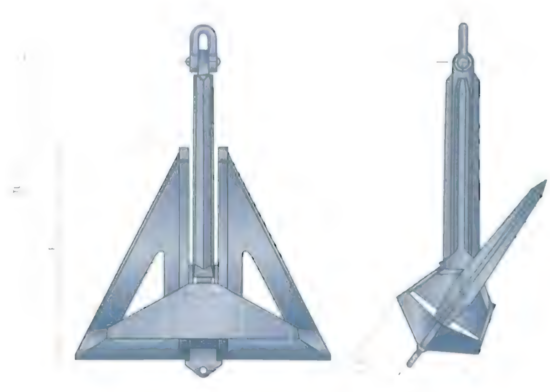
Anchor d'hone



Danforth anchor



AC-14 anchor



Flipper anchor

HHP anchors are allowed to be 25% lighter in weight because their holding force is twice as strong as that of a conventional anchor. The SHHP anchors can be 50% lighter in weight because their holding force is even larger, namely 4 times as large as a conventional anchor. However, this type of anchor is not accepted by Class for normal ships and can only be used on yachts and special craft.

For **Offshore and Dredging** special very high holding power anchors are used. They have to be laid in position by a tugboat, a so-called 'anchor-run boat' and also have to be lifted out by the same boat using a separate wire attached to the crown of the anchor. These anchors are certified as **Recoverable Mooring Systems.** An example of such an anchor is the Flipper Delta anchor.

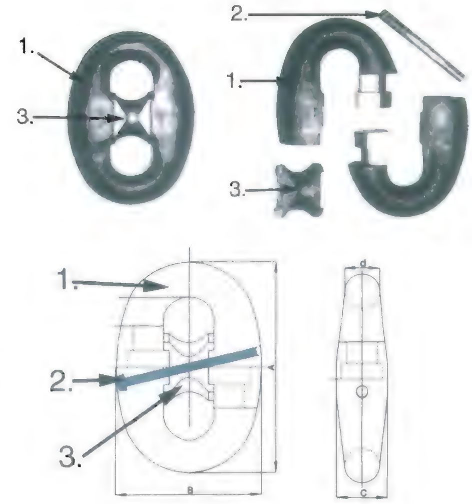
2.4 Anchor chain

The chain runs from the chain locker, through the spurling pipe, via the gypsy wheel of the windlass through the hawse pipe, to the anchor. The anchor chain consists of links with studs to prevent kinks in the chain (stud link chain).

The required strength and length of the chain can be determined with the aid of the equipment numbers in the previous table. This table also distinguishes two main types of material quality, namely U2 and U3. Not included in the table are the qualities U1, which has become obsolete, and U4, which is an offshore quality.

The anchor chain is composed of lengths (shackles), each with a length of 15 fathoms (15 x 1,83 = 27.5 meters). The shackles are interconnec-ted by a kenter shackle.

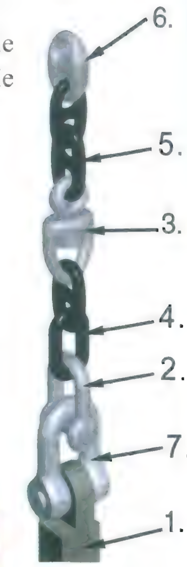
In order to keep track of the outboard chain length, the paying out and heaving in of the anchor can be monitored by markings near each kenter shackle. The markings are either white paint and/or wire wound around the studs. The kenter itself is red.



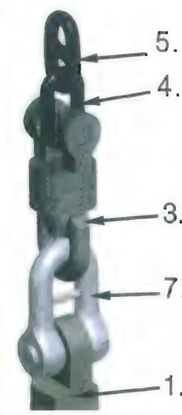
1. Half link
2. Locking pin
3. Stud

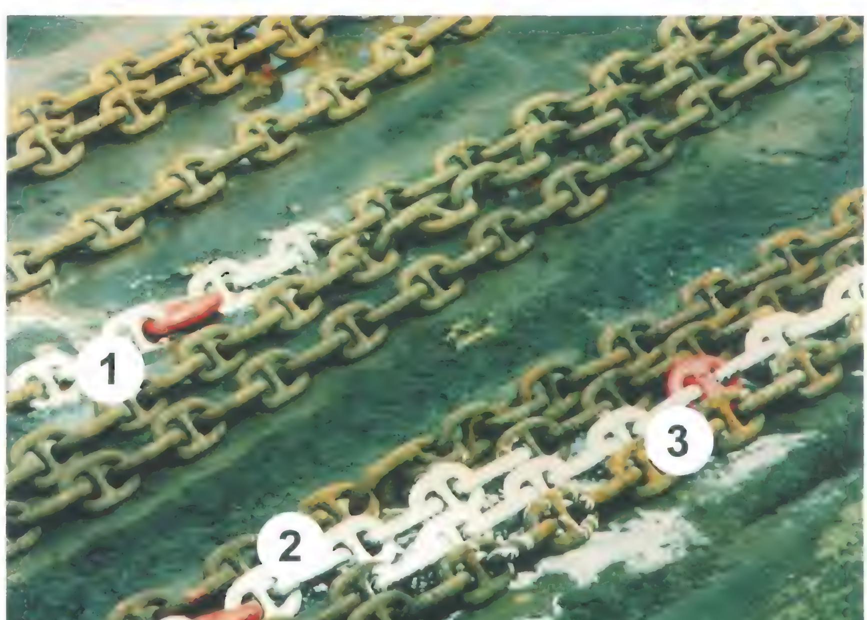
Kenter shackle

Description of the images below:
1. Anchor shank
2. Anchor / link
3. Swivel
4. Open link
5. Enlarged link
6. Kenter shackle
7. Crown shackle



Different ways to connect the anchor to the chain





81 mm U3 chain quality

1. 3rd length or 'shackle'
2. 6th length or 'shackle'
3. 7th length or 'shackle'

Page 1 of 1

CERTIFICATE FOR ANCHOR CHAIN CABLE AND CHAIN CABLE FITTINGS

LR Office	Date	Certificate number
Qingdao	31 July 2001	QDO 0150680/7

Client/Manufacturer	Purchaser
Zibo Anchor Chain Factory, Laiwu Steel Group, Ltd.	Chongqing Marine & Industries Co., Ltd.
Chain manufacturer (If different from above) -	Order number on manufacturer Z286
Testing house name and address (if different from above) -	Work's order number -
	Material certificate numbers 0000808

This certificate is issued to the above Client to certify that the Anchor Chain Cable and Chain Cable fittings†, detailed herein, have been made, examined and tested in accordance with the Rules and Regulations of Lloyd's Register of Shipping, and also in accordance with the schedules under the UK Anchor and Chain Cable Rules 1970 = Statutory Instruments 1453 (British Flag Ships Only)†

PARTICULARS OF FINISHED CHAIN CABLE AND FITTINGS

Chain grade U3a		Nominal Diameter (mm) 40.0	
Total length of chain cable (m) Nil	Length of link (mm) Nil	Breadth of link (mm) Nil	Mass (tonnes) Nil
Number of enlarged shackles Nil	Number of swivels Nil	Number of lugged joining shackles End Shackle:15 (Fifteen)	Number of lugless joining shackles Nil
Proof load applied kN/~~tf~~† 896.0	Break load applied kN/~~tf~~† 1280.0	Approved alternative procedure for break test applied Yes ☐ No ☐	
Break test frequency	Each (27.5m) length ☐	Every four (27.5m) lengths ☐	Each batch (fittings) ☒
Manufacturing process Forged		Heat treatment Quenched and Tempered	

MECHANICAL PROPERTIES - FINISHED CABLE AND FITTINGS

Cast number	Cable/ Fitting	Yield strength N/mm²	Tensile strength N/mm²	Elong. %	Red. of Area %	Impact value - Joules					Location in way/clear of weld
						Temp °C	1	2	3	Average	
T2001183	End Shackle	591	741	22	63	0	186	179	186	183	base

CHEMICAL COMPOSITION - AS STATED BY MANUFACTURER

Cast number	C%	Si%	Mn%	P%	S%	Al%	N%	Cr%	Cu%	Nb%	Ni%	V%	Mo%
T2001183	0.32	0.31	1.46	0.020	0.009	0.043	0.006	0.07	0.17	0.01	0.08	0.01	0.01

IDENTIFICATION MARKS

a) LR and Office	b) Certificate number	c) Proof load and grade
LR QDO	0150680/7-(1-15)	PL896KN U3

Signature - Surveyor to Lloyd's Register of Shipping Z.S.Lu for D.Q.Liu and self	**To be completed by the Surveyor verifying the equipment after placing on board** Signature - Surveyor to Lloyd's Register of Shipping
Date 31.07.2001	Date
	Chain cable placed on board (name of vessel)

†delete where not applicable

Should the Anchor Chain Cable or fittings described above be lost or destroyed, this certificate is to be returned to the Secretary of Lloyd's Register of Shipping, London, for cancellation. If the Anchor Chain Cable or fitting is impaired or otherwise altered, so as to destroy its identity with the certificate, the facts are to be reported to the Secretary, or one of LR's Surveyors in order that the certificate may be altered accordingly.

The paid out chain length can also be monitored electronically by sensors that carefully register how many times the gypsy wheel rotates. An advantage of this system is that when the anchor is hove in, the winch automatically slows down when the anchor chain is almost inside and stops when the anchor is home.

A D-shackle connects the anchor and chain. A **swivel** is usually fixed on the chain and allows the anchor to rotate independently. The swivel can also be connected directly to the anchor.

A water spray installation in the hawse pipe

Anchors in pocket

2.5 Hawse pipes and anchor pockets

The hawse pipe is a tube that leads from the shell plating to the forecastle deck. A **water spray** in the pipe cleans the chain during heaving of the anchor.
During heaving, the flukes of the anchor should be parallel to the ship's shell. A collar protects the part of the ship's shell around the hawse pipe. In addition, the plating is extra thick in this area.
Anchor pockets or recesses are sometimes made in the bow into which the anchors can be completely retracted.

The advantages of the anchor recesses:
- the anchors are protected from direct contact with waves
- a loose anchor cannot bang against the shell (important on passenger liners)
- damage to the shell by floating ice can be prevented
- prevention of fatigue damage to the anchor itself
- mooring wires do not get fouled

2.6 Chain stopper / cable stopper

The chain stopper absorbs the pull of the chain by diverting it to the hull. The chain stopper's holding force should be min. 80% of tensile breaking strength of the anchor chain. Furthermore, the hawse pipe's resistance absorbs 20% and the windlass should have a holding force of 45% of the minimum break load.

In most types of chain stoppers, the chain runs over a roller, sometimes equipped with a tensioner. The actual stopper is usually a heavy bar laid over the flat link and secured with a strong pin. The securing consists of a hook onto which both eyes of a steel wire are attached. This wire is put through a link of the chain and tensioned. This fixes the anchor in the recess thereby preventing banging of the anchor against the shell.

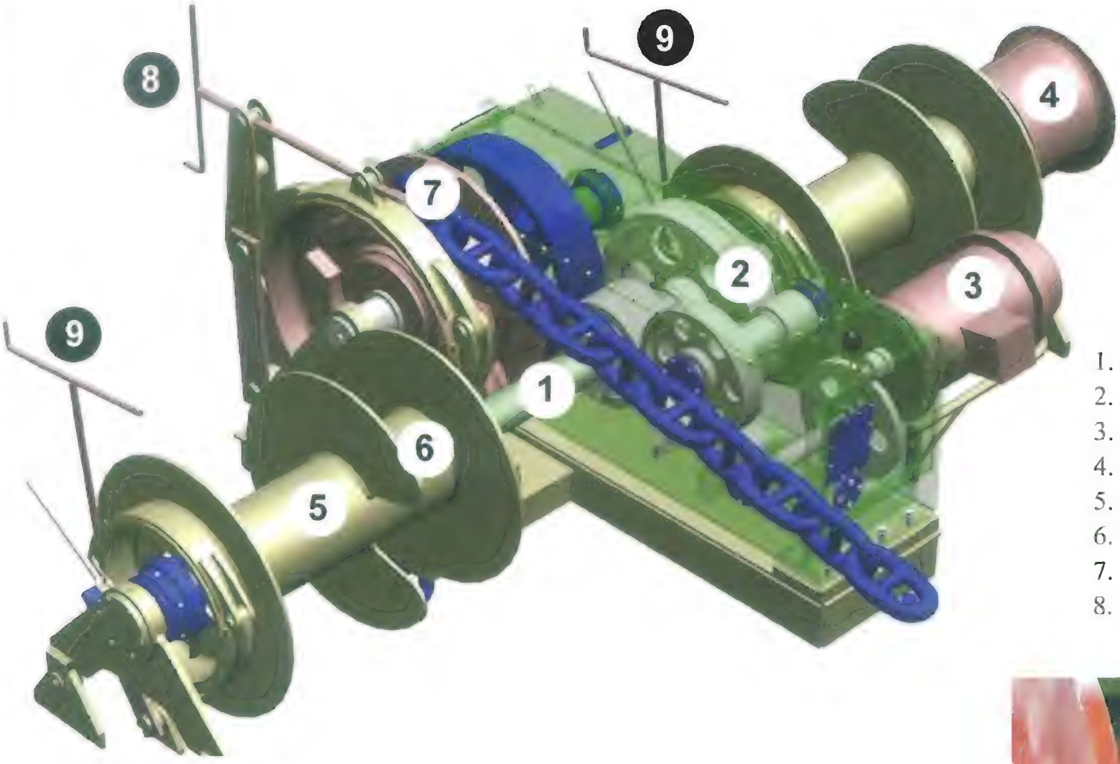
Cable stoppers are to be divided into anchor securings for when the vessel is at sea and riding at anchor. When the vessel is at sea, the anchor is held by the brake band and a securing wire or preferably a high tensile chain, through the chain cable and then attached to a strong point on the fo'c'sle deck. The windlass should not be engaged.

When riding at anchor the chain force on big ships is held by a transverse, hingeable bar, a **strong back**, incorporated in the guide roller above the hawse pipe secured on top of a flat link of the anchor chain, so that a vertical link cannot pass. The chain forces are then transferred to the ship's construction. A wire is insufficiently strong and vulnerable to chafing especially when not lashed through a link of the chain under a stud.

Chain stopper with tensioner

Chain stopper

1. Tensioner	3. Chain
2. Cable stopper	4. Guard



Anchor and mooring combined windlass / mooring winch

1. Main shaft
2. Gear box
3. Electric motor
4. Warping drum
5. Drum (storage part)
6. Drum (working part)
7. Gypsy wheel
8. Control lever for the band brake

Winches on the forecastle and on the quarter deck of a car ferry

The main shaft is rotates, the warping end is the only part that also rotates. The gypsy wheel and both drums are disconnected

2.7 Winches

Anchor winches are used to heave in and pay out the anchors and anchor chains in a controlled way. The same winch can be used to operate a mooring drum. A clutch is used to connect / disconnect the **gypsy wheel** or the mooring drum to the main shaft. The anchor can be hove in if the gypsy wheel is coupled to the main shaft.

Anchor winches normally are provided with a mooring drum via a separate clutch. The winch turns either the gypsy or the mooring drum, or both. The main shaft in most cases is horizontal, however, in rare cases it can be vertical, like a **capstan.**

The winches can be powered by:
- electricity - An electric motor rotates a cogwheel. The advantage of using an electric motor is that the noise is limited. Especially important on passenger liners.
- hydraulic systems - The cogwheels are driven by a hydraulic motor, which is connected to a hydraulic pump system located below the deck. Advantages of this system are that there is no risk of (electrical) sparks and furthermore, the system is gearless.
- electric hydraulic. The set of pumps is incorporated in the winch instead of below deck. This means that there is no need for piping systems for the hydraulic oil.
- Steam.

Claw clutch out and in

1. Bearing
2. Sliding claw
3. Fixed claw

Bitter end connection

A rope should never stay on the warping drum because the force exerted by the ship may well exceed the pulling force of the warping drum. The warping drum can absorb equal amounts of pulling force and brake force; the brake force of the drums, however, is three times as much as the pulling force due to the band brake.

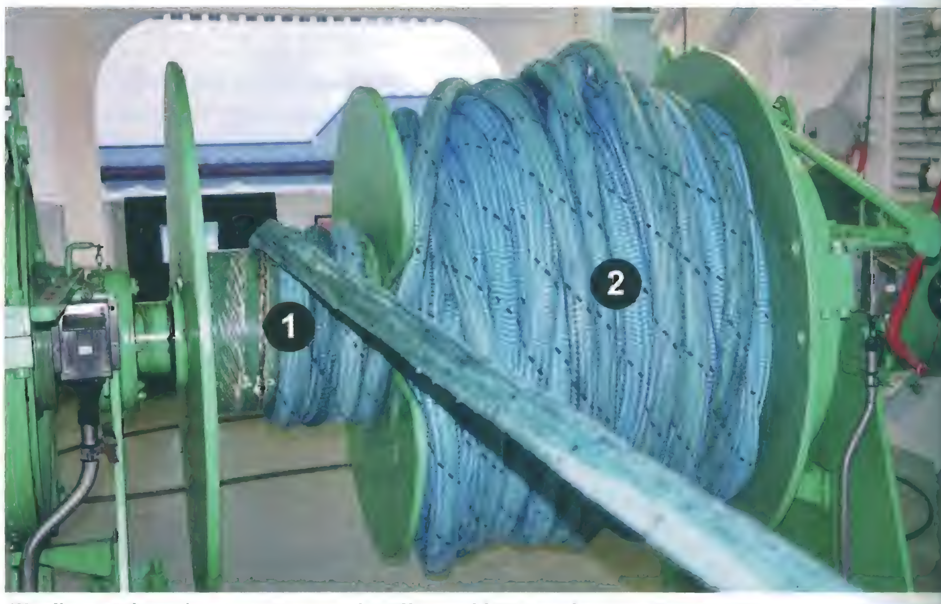
Below:
1. Working part
2. Storage part
3. Warping end

2.8 Chain locker

The anchor chain enters the chain locker via the **spurling pipes.** Chain lockers are high and narrow, making them self-trimming. This means that the stacked chain can not fall over in bad weather. The end of the chain, the **bitter end,** is connected to an end connection in the chain locker, with a release possibility outside the locker. On very large ships, the connection is often a weak link, which breaks when the chains runs out accidentally. This way the chain locker and fo'c'sle deck will not be damaged, because a heavy chain, when running, cannot be stopped.

A grating (plate with holes) on the bottom of the chain locker makes sure that water, rust and mud can fall to a space below the chain locker. This has a separate manhole entrance for cleaning purposes. A (manual) bilge pump drains the water. In emergencies, the chain can be released by the bitter end outside the chain locker.

Possible types of **chain release** (bitter-end connection):
- remove the pin out of the last link of the chain with a hammer. The pin is located either below deck outside the chain locker or on deck, next to the windlass.
- a weak link in the bitter end connection ensures that the chain breaks loose when the stress becomes too high. The breaking force must be less than the maximum holding force of the chain.
- the hand wheel can be used to release or attach the chain.



Windlass with anchor securing, guide roller and bitter end connections

Anchor windlass, with on the same shaft as the gipsy a mooring drum and warping head

3 Mooring gear

A ship's mooring system is designed to moor a ship with a standard lay-out on a standard jetty, with bollards at regular distances. A ship is therefore equipped with winches, with wires or ropes on drums (no hands) and with additional ropes, which can be paid out by hand and tightened using the warping heads.
Tankers have, through an international standard system of oil companies, a standardized mooring system.

3.1 Winches

– **Drum**
A winch drum can be made in two ways - a straight drum and a drum in two parts for tensioning and storage. If the drum has one part, it serves both as head (storage) and as drawing and pulling drum. These types of drums are only suitable for steel wire and certain synthetics. If force is applied to a synthetic hawser, it may not slip through the layers of rope below. If this happens, the rope fouls. Sorting the rope out again takes a lot of time. If the drum consists of two parts, then the small part is the working drum and the other part is the storage part. The tension in a rope (with a maximum of two layers) may only be applied on the working drum.

Suppose that the diameter of the drum is 30 cm, and 5 windings fit next to each other in two layers, then the pulling drum can pull in 10 m. of rope.

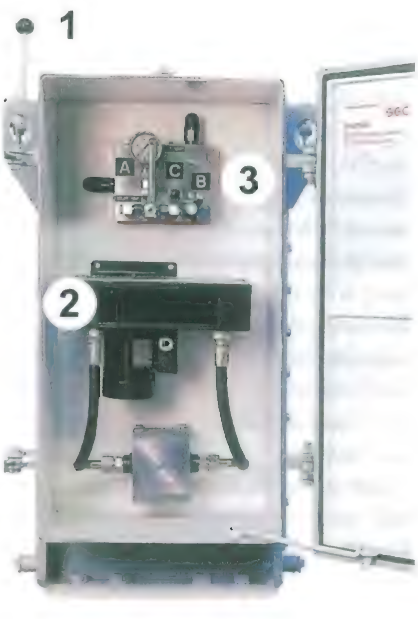
If the MBL (minimum break load) of the ropes is 100%, then the holding capacity of the drum is 80%, and the pulling force is approximately 1/3 of this. This rule applies to all the drums mentioned.

Warping Head
The warping head is used:
- to heave in extra ropes, set them up and fasten them on the bollards
- to move the ship alongside the quay over short distances. If the warping drum is used, the gypsy wheels and the drums must not be coupled to the main shaft which would engage the anchor cable.

Foredeck of a tanker

1. Warping head
2. Drum
3. Bollards
4. Eyes to connect the stoppers
5. Guide roller (fairlead)
6. Center lead
7. Leadway
8. Head line
9. Forward spring

Self tensioning winches
Self tensioning winches can be adjusted to maintain a certain holding force. If this value is exceeded, then the winch **automatically adjusts** the length of wire to the new force (too much holding force: slacking; too little holding force: heaving). This system is frequently used by ships that load and discharge quickly (container ships and Ro-Ro vessels) or if there is a large tidal range in the port.



Control for the self tensioning winch

1. Control lever for the winch
2. Cooling fan
3. Control for the self tension

– **Capstans**
The capstan consists of a warping drum with a vertical drive shaft that is driven either electrically, hydraulically or electro-hydraulically. The capstan is usually placed on the aft ship and, if the ship is very long, on the sides. If the capstan is combined with a gypsy wheel, it can be used to control the (stern) anchor i.e. a vertical anchor windlass.

Capstan

3.2 Mooring gear auxiliaries

One or more winches can be placed on the fore ship, depending on the size of the ship and the preference of the owner. As shown in the picture, the warping drum, bollard and fairlead are preferably positioned in a straight line.

Rollers, chocks, guide pulleys and bollards

A rope is guided from the shore via a **Panama chock**, through the bulwark to a bollard or winch. The Panama chock must be able to withstand large forces because the direction of the rope changes inside the Panama chock. The Panama chock must be curved to prevent wear of the rope.

Roller fairleads can also be made of vertical and horizontal rollers. Their function is the same as the panama chock. However, the roller fairlead causes less wear to the ropes.

Panama chock and roller fairlead

Bollard

1. Guide roller
2. Nose
3. Stopper eye

Panama chock

Rollers on deck serve to change the direction of the ropes. Both the roller fairleads and the guide pulleys are able to withstand a maximum of 32 tons of pulling force depending on the ship's size.

Bollards transfer the mooring forces to the ship's hull. The outsides of the bollards have a nose, which prevents the first few turns of the rope from slipping upwards. Above or below this, there is an eye to which the rope stopper can be attached. The stopper absorbs the forces in the rope temporarily so that the rope can be taken off the warping drum and placed on the bollard. The double bollard is provided with two ridges to prevent the rope from moving. A stopper lug serves as a rope stopper.

For the non-moving parts like Panama chocks, the allowed force is 1/5 of the maximum static force that this part is able to sustain.

3.3 Emergency towing system for tankers

In recent years a number of environmental disasters involving tankers has shown how difficult it is to connect with a ship in distress. The IMO demands that tankers with a carrying capacity of more than 20,000 tons have an emergency towing connection forward and aft. Forward this is a stopper, which holds a standard chain when pulled through from outside to inside (the same stopper the tanker uses when mooring on a single buoy). Aft, it has to be a prepared system. This means a rope or wire in the water with a messenger buoy, ready to be picked up and fastened by a tugboat that can be deployed by one man.

Buoy of an emergency towing system

4. Rigging

4.1 Cables and ropes

General

Cables are used on ships:

a. to moor the ship and maintain its position at a jetty and for towing
b. for the cargo gear
c. in fishing and dredging

The cables mentioned in a. are usually made of rope and called hawsers or lines. The cables used in b. and c. generally are steel cables. The latter are described in more detail in the section "description of common cables".

Rope can be made from either natural or **synthetic fibers.** Nowadays, with a few exceptions, most ropes are made from synthetic fibers. The synthetic fibers are manufactured from mineral oil products that have undergone a chemical process.
The rotation of the threads is opposite to the strands, preventing the rope from unlaying. Below some (of the many) types of ropes are categorized according to the way they have been stranded (plaited).

Some rope types have a mantle. The purpose of the mantle is to keep the strands in the core together. This has the advantage that the strands in the core can be arranged in a parallel fashion, giving the maximum tensile strength. The mantle itself rarely contributes to the tensile strength. The threads in the core need not be resistant to wear as the mantle provides wear resistance. Therefore it is important that the wear resistance of the mantle is higher than the wear resistance of the core. A mantle keeps the cable round and compact, which reduces sensitivity to wear.

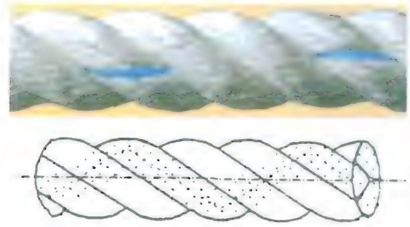
TABLE OF EQUIPMENT FOR SELF-PROPELLED OCEAN GOING VESSELS

The table of equipment links the so-called equipment number to the composition, sizes and quality of anchors, chains and mooring ropes on ocean-going vessels. The equipment number is normally calculated in the design stage of the vessel. This table is accepted and used by all main classification societies.

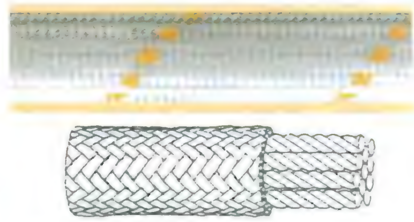
											MOORING LINES
						LENGTH (m)	MBL (kN)	QUANTITY	LENGTH (m)	MBL EACH (kN)
840- 910	2640	1980	467,5	46	40	190	520	4	170	200
910- 980	2850	2140	495	48	42	190	560	4	170	215
980-1060	3060	2295	495	50	44	200	600	4	180	230
1060-1140	3300	2475	495	50	46	200	645	4	180	250
1140-1220	3540	2655	522,5	52	46	200	690	4	180	270
1220-1300	3780	2835	522,5	54	48	200	740	4	180	285
1300-1390	4050	3040	522,5	56	50	200	785	4	180	305
1390-1480	4320	3240	550	58	50	200	835	4	180	325
1480-1570	4590	3445	550	60	52	220	890	5	190	325
1570-1670	4890	3670	550	62	54	220	940	5	190	335
1670-1790	5250	3940	577,5	64	56	220	1025	5	190	350

Some core types that can be present in core-with-a-mantle cables:
- braided
- stranded
- parallel strands
- parallel threads

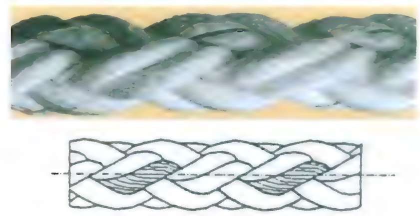
The characteristics that are important when using or buying rope:
- MBF (Minimum Break Force) - minimum force in kN needed to break the rope
- elasticity
- density - the larger the density, the heavier the rope. It is important to know whether the density is smaller or larger than 1,000 t/m³, in other words: does the rope sink or float.
- UV-resistance. After several years, sunlight can degrade a rope.
- wear resistance
- construction - the number of strands and the way that the rope is plaited; presence of a mantle
- water absorption - expressed as a percentage of the rope's weight
- backlash or snapback - indicates if, in case of breaking, the rope falls "dead" on the deck or snaps back. Rubber has a large backlash.
- creep limit - lengthening of the cable under constant tension
- chemical durability - indicates how well the rope can resist chemicals
- knot or splice - in a cable this can reduce the strength by as much as 50%
- TCLL value (thousand cycle load level) - the cyclic load level as a percentage and as an absolute value of the maximum load under wet conditions. This is the load at which a cable will break when it has undergone the load a 1000 times. For example, if the TCLL value of a 100 ton/f cable is 50%, or 50 ton/f, then the cable will break if subjected to a 50 ton/f load a 1000 times.



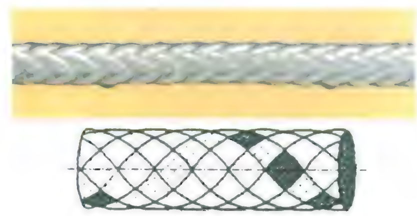
3-strand



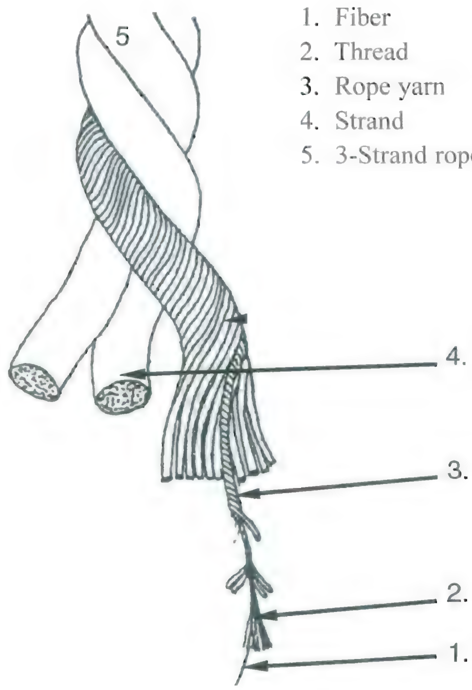
Parallel fiber core with mantle



4x2-strand braided



Braided



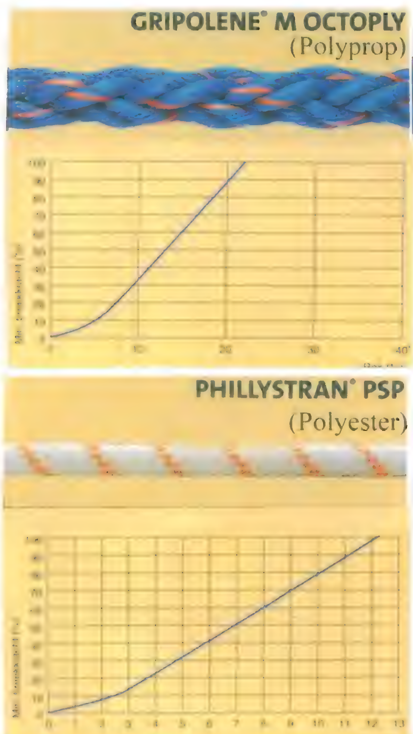
1. Fiber
2. Thread
3. Rope yarn
4. Strand
5. 3-Strand rope

The drawing above shows how a rope can be composed

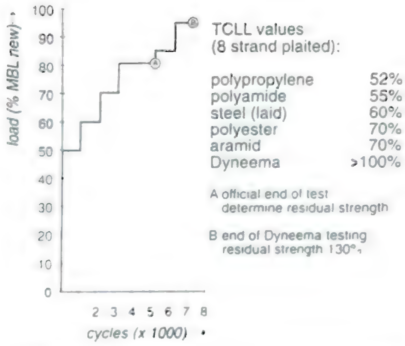
4.2 Description of common cables

a. High-grade cables
b. Polyamide
c. Polyester
d. Polyolefines
e. Natural rope
f. Steel cables

a. High-grade cables
Aramide and High Module Poly-Ethylene (HMPE) are high-grade cables. Kevlar, Twaron and Technora are aramide brand names and Dyneema and Spectra are HMPE-brands. The difference between the two types is that aramide has a lower (thus better) creep, but aramide sinks whereas HMPE floats. High-grade cables are relatively new products and strength wise they are comparable to steel cable of the same diameter. However, the price is 5 -10 times higher than steel cables.
Advantages over steel cables are:
- light weight
- easy to handle
- non-conductive
- small backlash



These graphs show that the elasticity of polypropylene is greater than that of polyester. At maximum load, the polypropylene stretches by 20% and the polyester by 12%.



This graph shows the TCLL-values for a number of rope types

All relying on one bollard

b. Polyamide
Polyamide is better known as **nylon.** Polyamide ropes sink (density > 1,000 kg/m^3) and absorb water after being in contact with water a few days. The absorption of water adds 4% to the rope's weight. This can reduce the MBF by 20%. Polyamides have a large elasticity. A consequence of this is the backlash when parting. The rope sweeps over the deck and endangers the people present. Certain types of polyamides can be spliced and re-used after the rope has snapped. However, especially cheap ropes are disposed of when they snap, and a new rope is ordered.

c. Polyester
Polyesters are very resistant to wear and very durable, both in wet and dry conditions. Its mechanical characteristics resemble nylon, except that it is **more resistant to wear.** Furthermore, polyester is more expensive. The density of nylon (1.14) is lower than of polyester (1.38) and the energy absorbing capacity of nylon is higher, making it more suitable to absorb large force variations. For this reason, nylon is often used as a stretcher, to protect steel cables from large shock loads.

d. Polyolefines
There are two types of polyolefine rope, namely "High Performance Ropes" and "Standard Ropes". The difference between these two lies not just in the MBF, but also in qualities like **UV-sensitivity** and wear resistance, which increase the durability of the rope. High performance ropes can also be found with a mantle.

Polypropylene, polyethylene and mixtures of these compounds are polyolefines. Many high performance ropes like the Tipo-eight are also polyolefines. Polyprop is a polyolefine-rope that is often used.

Its advantages are:
- it floats
- it is relatively cheap

The disadvantages are:
- it is not very resistant to wear
- it has a low TCLL-value
- it has a short lifespan

Towing wire with a stretcher

6X36WS + IWRC 1960 N/MM^2

QUALITY	• galvanised	TYPE OF LAY	• regular lay
TENSILE STRENGTH	• 1960 N/mm^2	DIRECTION OF LAY	• right hand
TOTAL NUMBER OF STRANDS	• 13	GREASING	• yes
TOTAL NUMBER OF WIRES	• 265	ON REQUEST	• lang lay
TYPE OF CORE	• IWRC		• ungalvanised
NUMBER OF OUTER WIRES	• 84		• dry
NUMBER OF OUTER STRANDS	• 6		• left hand lay

Standard wire rope with steel core, general purpose use

Nominal Diameter (mm)	MBF (kN)
8	44,7
9	51,0
10	69,8
11	84,4
12	100,0

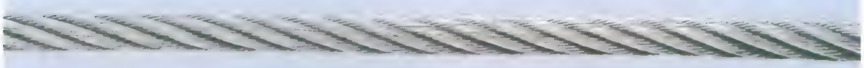
7X19

QUALITY	• galvanised	TYPE OF LAY	• regular lay
TENSILE STRENGTH	• 1770 N/mm^2	DIRECTION OF LAY	• right hand lay
TOTAL NUMBER OF STRANDS	• 7	GREASING	• no
TOTAL NUMBER OF WIRES	• 133	ON REQUEST	• ungalvanised
TYPE OF CORE	•WSC		• greased
NUMBER OF OUTER WIRES	• 36		• left hand lay
NUMBER OF OUTER STRANDS	• 6		

Standard wire rope, mainly used in small diameters on winches

Nominal Diameter (mm)	MBF (kN)
8	37,6
10	58,7
12	84,6
14	115

6X19 + FC



QUALITY	• galvanised	TYPE OF LAY	• regular lay
TENSILE STRENGTH	• 1770 N/mm^2	DIRECTION OF LAY	• right hand lay
TOTAL NUMBER OF STRANDS	• 6	GREASING	• no
TOTAL NUMBER OF WIRES	• 114	ON REQUEST	• ungalvanised
TYPE OF CORE	• fibre		• greased
NUMBER OF OUTER WIRES	• 72		• left hand lay
NUMBER OF OUTER STRANDS	• 6		

Wire rope with fiber core

Nominal Diameter (mm)	MBF (kN)
8	34,8
10	54,4
12	78,3
14	107

19X7

QUALITY	• galvanised	TYPE OF LAY	• regular lay
TENSILE STRENGTH	• 1960 N/mm^2	DIRECTION OF LAY	• right hand lay
TOTAL NUMBER OF STRANDS	• 19	GREASING	• yes
TOTAL NUMBER OF WIRES	• 133	ON REQUEST	• lang lay
TYPE OF CORE	• WSC		• ungalvanised
NUMBER OF OUTER WIRES	• 72		• dry
NUMBER OF OUTER STRANDS	• 12		• left hand lay

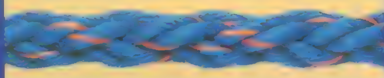
Rotation resistant wire, used as hoisting rope

Nominal Diameter (mm)	MBF (kN)
8	41,1
10	64,3
12	92,6
14	126

PHILLYSTRAN® PSP

Nominal Diameter (mm)	MBF (kN)
34	400
40	578
46	778
53	978
60	1270

GRIPOLENE® M OCTOPLY



SPECIFIC GRAVITY	[illegible]	CONSTRUCTION	[illegible]
UV RESISTANCE	[illegible]	TCLL VALUE	[illegible]
ABRASION RESISTANCE	[illegible]	COLOUR	[illegible]
CHEMICAL RESISTANCE	[illegible]	MARKER YARN	[illegible]
ELONGATION	[illegible]	WATERABSORP.	[illegible]
MELTING POINT	[illegible]		

Nominal Diameter (mm)	MBF (kN)
32	132
36	168
40	201
44	241
48	280

TIPTOLON® 3-STRAND

SPECIFIC GRAVITY	[illegible]	ELONGATION AT BREAK	[illegible]
UV RESISTANCE	[illegible]	MELTING POINT	[illegible]
ABRASION RESISTANCE	[illegible]	COLOUR	[illegible]
CHEMICAL RESISTANCE	[illegible]	WATERABSORP	[illegible]

Nominal Diameter (mm)	MBF (kN)
32	196
36	244
40	294
44	351
48	412

MANILLA II 3-STRAND

SPECIFIC GRAVITY	[illegible]	CHEMICAL RESISTANCE	[illegible]
UV RESISTANCE	[illegible]	ELONGATION AT BREAK	[illegible]
ABRASION RESISTANCE	[illegible]	WATERABSORP	[illegible]

Nominal Diameter (mm)	MBF (kN)
32	77,2
36	94,6
40	118
44	140
48	165

e. Natural rope

Natural fiber rope has been replaced on most ships by synthetic ropes. In general, the only type of natural rope still in use on ships is **manilla rope.** Manilla rope is manufactured from the abaca fiber present in the leaf stalks of the manilla plant.

Although the resistance to chemicals and UV-light is good, the MBF is about 2-8 times smaller than the MBF of synthetic ropes.

Manilla on ships is used for the pilot ladder, boat ropes of lifeboats and helicopter nets.

The reason for this is:

- manilla is less sensitive to fire and burns slower
- manilla is rough and hairy, therefore it does not slip easily, especially when wet.

f. Steel wire ropes

Steel cables or wire ropes have advantages and disadvantages. They are strong, cheap, have little elongation under tension, have a high wear resistance, but they are heavy, and they rust.

They are used where the circumstances allow or demand it, for instance for hoisting and luffing wires in cranes, mooring wires for tankers and bulk carriers, anchor wires in dredging and offshore and towing wires for fishing and tugboats. In case of fire they are not immediately destroyed.

Steel wires are available in numerous constructions, depending on the requirements.

There are basically two steel tensile strength grades: 1770 N/mm^2 and 1960 N/mm^2. Cables are made of a number of strands, turned in a long spiral around a core. The strands consist of a number of wires that are usually galvanized.

An eye is spliced into a rope

For flexible wire, the core is rope, and when flexibility is not necessary, the core is steel. A steel core makes a stronger wire. Rope core when oiled, lubricates the wire, but allows deformation under stress and bending. Steel wires need maintenance. Regularly greasing is essential.

The strength is optimal when different sizes of wires are used in one strand, so that the space between the wires is optimally filled. This is done in cables made according to the Warrington-Seal (WS); the section is then optimally filled with steel and water permeability is less.

Like ordinary rope, there are **right hand** and **left hand** laid cables. Analogous to synthetic rope, the direction of rotation of strands and wires is mostly opposite, called "**ordinary lay**".

Other constructions are **Cross-lay, Lang's Lay, Non-Rotating,** etc. When wires and strands have the same direction of rotation, it is possibile they will open. These types of wires are only to be used where the both ends are fixed, such as mast stays and bridge suspensions. Non-Rotating cables are always cross-lay.

During the fabrication process the wires in the strands can be pre-formed into the helical form for the finished state to reduce internal stresses in the rope. This prevents unspinning, and a broken wire does not stick out. The construction of steel wire is given in a formula.

For example, Galvanised - Diam. 36 mm, 6 x 36 ws + iwrc.

It means 36 mm diameter, 6 strands with 36 galvanised wires each, warrington seal (ws), and an independent wire rope core (irwc). Warrington seal is a means of constructing a wire rope from wires of different diameters, so that water ingress is limited.

Steel wire is generally galvanized, but untreated steel wires also exist, and for special purposes stainless steel is used.

4.3 Various parts

Various rigging parts are explained on these pages:

- end connections
- shackles
- turnbuckles or bottle screws
- thimbles
- sockets.

A Talurit clamp is an aluminum bush, which is pressed under high pressure at the position where a splice would be normally, replacing the time-consuming splicing. The pressing makes the original oval shaped bush into a cylindrical clamp, with the strength of the replaced splice. A Talurit clamp is not to be bent.

Life boat hoisted with 19x7 steel wires

End links

1. Gaff socket with rolled connection
2. Cast spelter socket
3. Rolled eye terminal
4. Thimbled Talurit eye
5. Spliced eye with thimble
6. Thimbled Flemish eye, swaged.
7. Wedge socket (not allowed for hoisting).

– **End connections**
End connections are needed to connect a wire to something else. Often shackles are used for the connection.

– **Safety hook**
A safety hook is shown in the figure below. It prevents the load from falling off the hook, even if the load is resting. The hook can only be opened by pressing the safety pin.

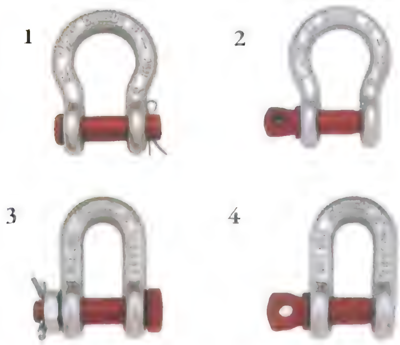
Safety hook

1. Brand or type marking
2. Chain size (chain 7/8 of an inch)
3. Class, grade 8 (high-grade steel)
4. Safety pin
5. Spring

– **Thimbles**
A thimble is a ring inside a spliced eye to enlarge the radius of the wire in a splice, e.g. the pin of a shackle, thus protecting the wire and is usually made of galvanized steel. It function is to protect the eye of a cable from wear and damage.


Thimble

– **Shackles**
Shackles can be divided into Bow shackles and D-shackles. The light types can be closed with a screw-bolt, the heavy types with a bolt and nut. These can come with or without a locking pin. Their general purpose is to connect certain parts to each other or to the ship. The Safe Working Load (SWL) can vary from 0.5 tons up to 1000 tons and more.



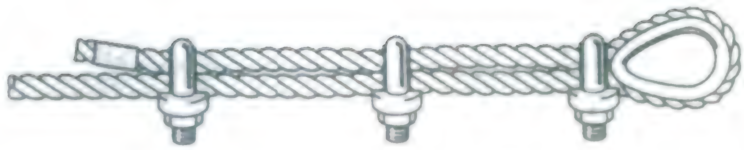
High tensile steel shackles. To obtain this high strength, after forging the shackles are subjected to heat treatment. (Quenched and Tempered)

1. Bow shackle with safety pin
2. Bow shackle with screw-bolt
3. D-shackle with safety bolt and nut
4. D-shackle with screw-bolt

– **Turnbuckles**
Turnbuckles are used to connect and tension steel wires or lashing bars. The bottle screw consists of two screws, one with a left screw thread and the other with a right screw thread. These are connected by a house.

Turnbuckle

1. Gaff
2. House
3. Thread - one left, one right handed
4. Eye

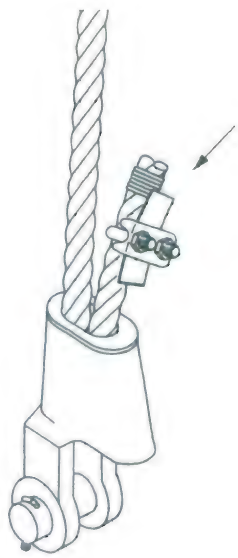


This is the correct way of applying the wire clamps to a cable (all U-bolts on the non-pulling part of the cable)

– **Steel wire clamps**

A steel wire clamp can be used to quickly make an eye in a cable. The U-bolt of the clamps should be attached to the part of the cable that is free from pulling forces.

Steel wire clamps may not be used for lifting purposes, except with for guys and keg sockets to make sure that the cable does not slip.



(Compulsory) wire clamp on a keg socket

– **Slings**

When lifting objects, slings are often needed. A **sling** is a wire with an eye spliced or clamped at each end. The eye can be long or short, depending on the purpose.

When the item to be lifted has lugs welded on it, a sling with Talurits and shackles can be used. In other cases long eyes are more versatile.

These eyes can be Talurit clamped, but a Flemish eye, with a swaged clamp is better.

A **Flemish eye** is a very simple but very strong splice. From a wire with an even number of strands, the strands are turned loose over the double length of the eye. Over that length the wire is split in two sets of strands.

Half the strands are bent in one direction, the other half in the other direction, meeting together in opposite directions, forming an eye. The strands are turned into each other, forming a wire. Where the ends come together a conical steel bush is placed on forehand, which is pressed together, preventing the wire ends from jumping loose.

The strongest sling is the **grommet.** A wire is turned around a circular rod, about six times the circumference forming a cable, after which the rod is pulled out, and the wires, acting as strands, remain, turned around themselves. The ends are tucked inside the rope.

A **grommet** is very flexible and strong. The heaviest grommets, for offshore lifts, reach a calculated MBL of 7500 tons. Testing is not possible, but the MBL of the individual wires is a known figure, found from a test sample.

Cable-laid slings are very heavy cables, constructed from steel cables with varying diameters, to fill the available diameter as solidly as possible. Eyes are spliced at each end. The rope diameter can go as high as 350 mm. The calculated MBL can go as high as 4000 tons.

– **Fabric Slings**

Modern slings are fabric, woven from modern fibers very light and strong. Band-type slings are made, with one disadvantage; they can easily be damaged by sharp items. But strength-weight ratios can be extremely high, when modern fibers, such as Dyneema, Aramide, or other carbons are used. Very flexible and soft slings are made from Dyneema in long straight threads, inside a canvas tubing. This type of sling is very friendly to machined or polished steel objects.

Cable-laid sling

Spreader with hook, SWL 6000 tons

4.4 Forces and stresses

Some definitions

Safe Working Load (SWL) or Working Load Limit (WLL) is the maximum acceptable load on an item (shackle, hook, wire, derrick, crane, etc.).

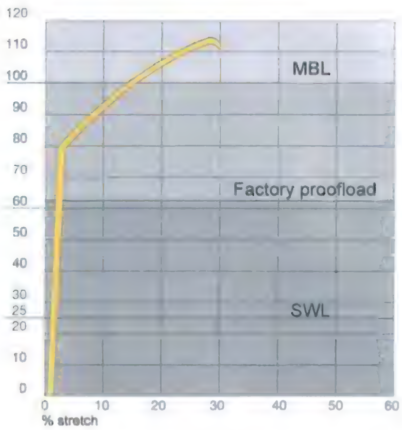
Minimum Breaking Load (MBL) is the guaranteed minimum load at which an item, when tested to destruction, will fail. So, on average, most items will fail at a higher load. The load-stretch diagram below shows that the tested chain actually failed at a higher load than the MBL. The diagram also shows that proof loading by the manufacturer is done 2.5 times the safe working load. For a re-certification test, the proof load will be 2 times the SWL.

Figures normally used for the ratio WLL/MBL (or SWL/MBL) are:

chains -	1 : 4
steel wires and shackles -	1 : 5
ropes -	1 : 6 or 1 : 7

Heavy-duty bow shackles ready for testing

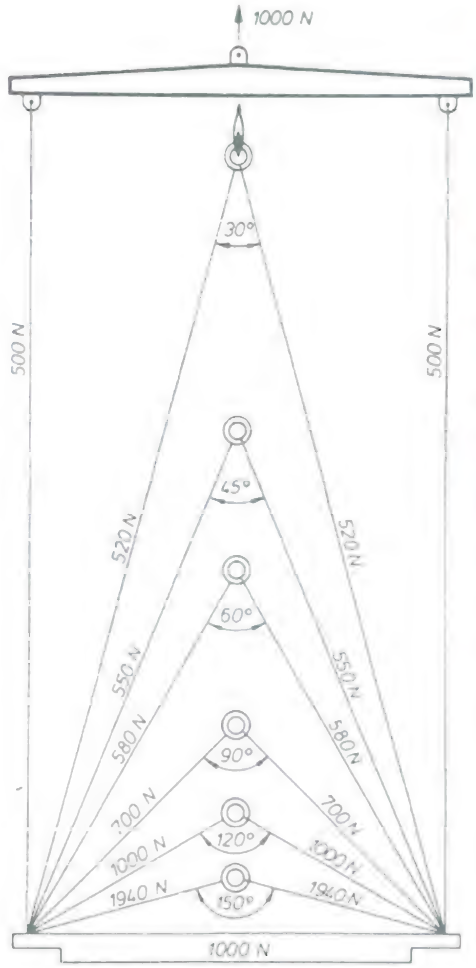
Blocks with rams horns of heavy cargo gear (400 tons SWL)



Load/stretch diagram of a grade 8 chain

– **Forces in wires**

The figure on the right shows the forces in a wire when a weight of 1000 N is lifted, and how the force in a rope or wire increases as a function of the angle between the components. When that angle exceeds 90° the increase is excessive. Between 120° and 150° the forces run up to 1950 N. The angle is therefore not allowed to exceed 120°. The material used for the wire does not influence the forces.



For heavy or large loads spreaders are used

CHAPTER 11

Engine room

1. Propulsion

The ship's propulsion is normally done by propellers and in most cases by only one. That propeller is rotated via a shafting system usually driven by a diesel engine. Again in most cases the propeller is fixed pitch, i.e. a so-called monobloc casting. The shafting consists of the propeller shaft or tail shaft and at least one intermediate shaft. The propeller normally is cast bronze (copper , nickel, aluminum); the shafting is of forged steel.

As a consequence of the application of a fixed pitch propeller, the main engine is normally a directly reversible diesel engine. A reversing gear box is only found in combination with small engines.

Systems with more than one propeller are found on fast ships, such as passenger ships and ships which are restricted by draft, or where the total power needed is too much for one propeller.

The following is a description of a normal engine room of an average cargo ship.

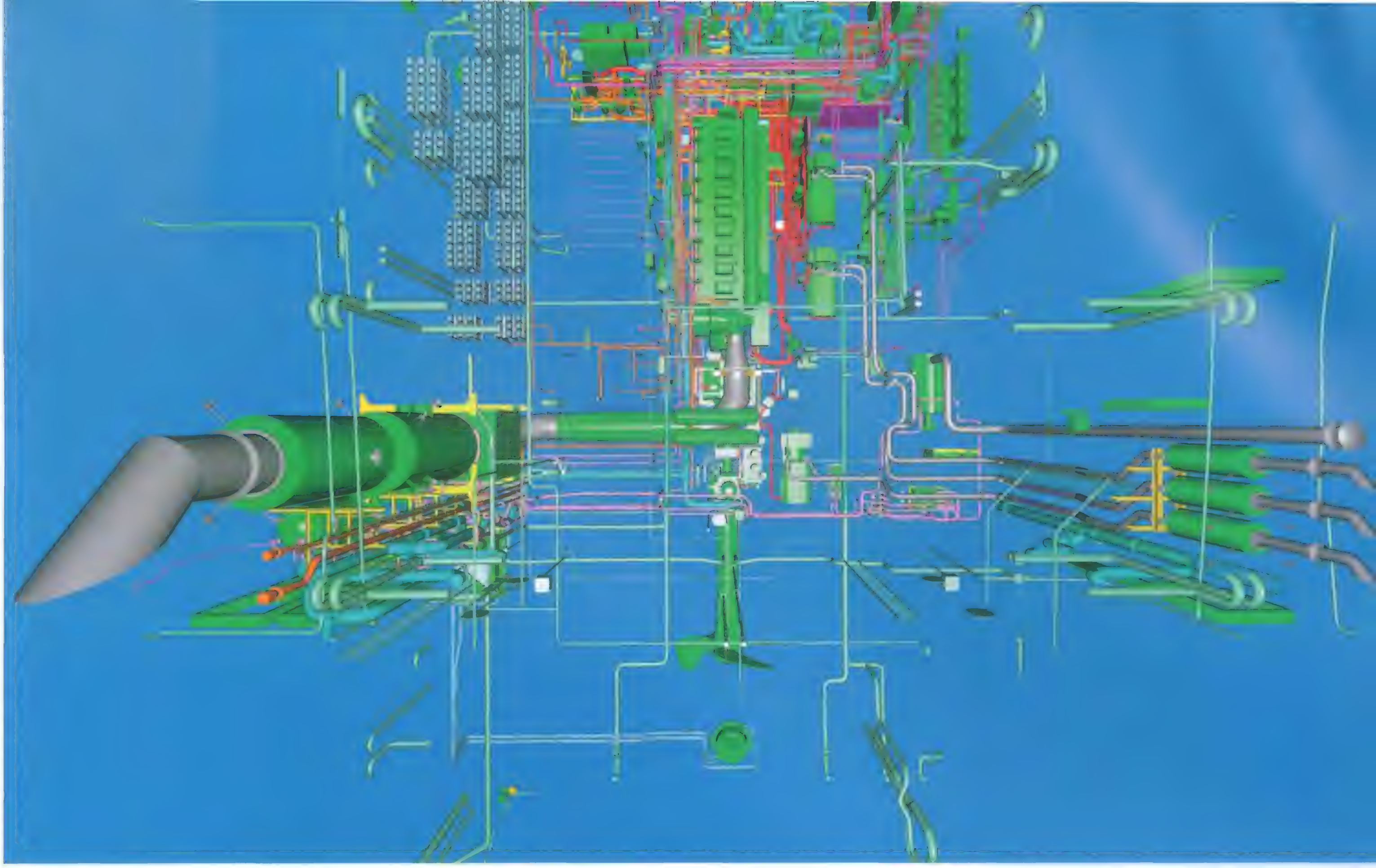
In most ships the engine room is installed aft and is **compressed** to a minimum length, to leave as much length as possible for cargo and to make the ship no longer than necessary. However, in the finer built hulls, such as the larger container ships the engine room is located further forward, about one third from aft. Modern passenger ships and Ro-Ro vessels have their engine room spread over a large part of the ship's length, limited in height, to create a minimum loss of vertical space where cabins or vehicles can be located.

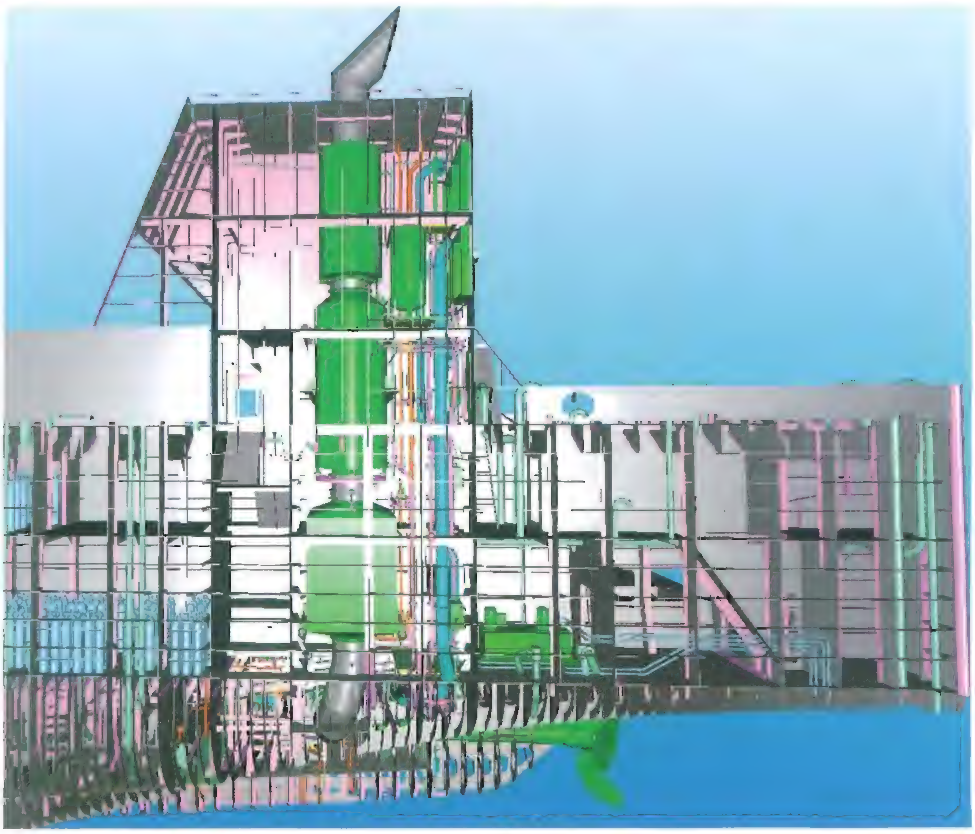
Various components for propulsion and power generation are located in the engine room - main engine(s), generators, salt and freshwater cooling water system, lubricating oil system, starting air system, fuel system, exhaust, working air system, and all kinds of auxiliary systems like bilge and ballast systems, freshwater system, working air system, etc. Air conditioning is normally fitted in a separate room, with the refrigeration system. The engine room also contains various storage tanks for lubricating oil, clean fuel oil, etc.
A ship's engine room is **complex, complete and compact.**

An engine room of an average cargo ship normally contains one main engine.

RPM: Revolutions Per Minute

Installing a main engine on its foundation

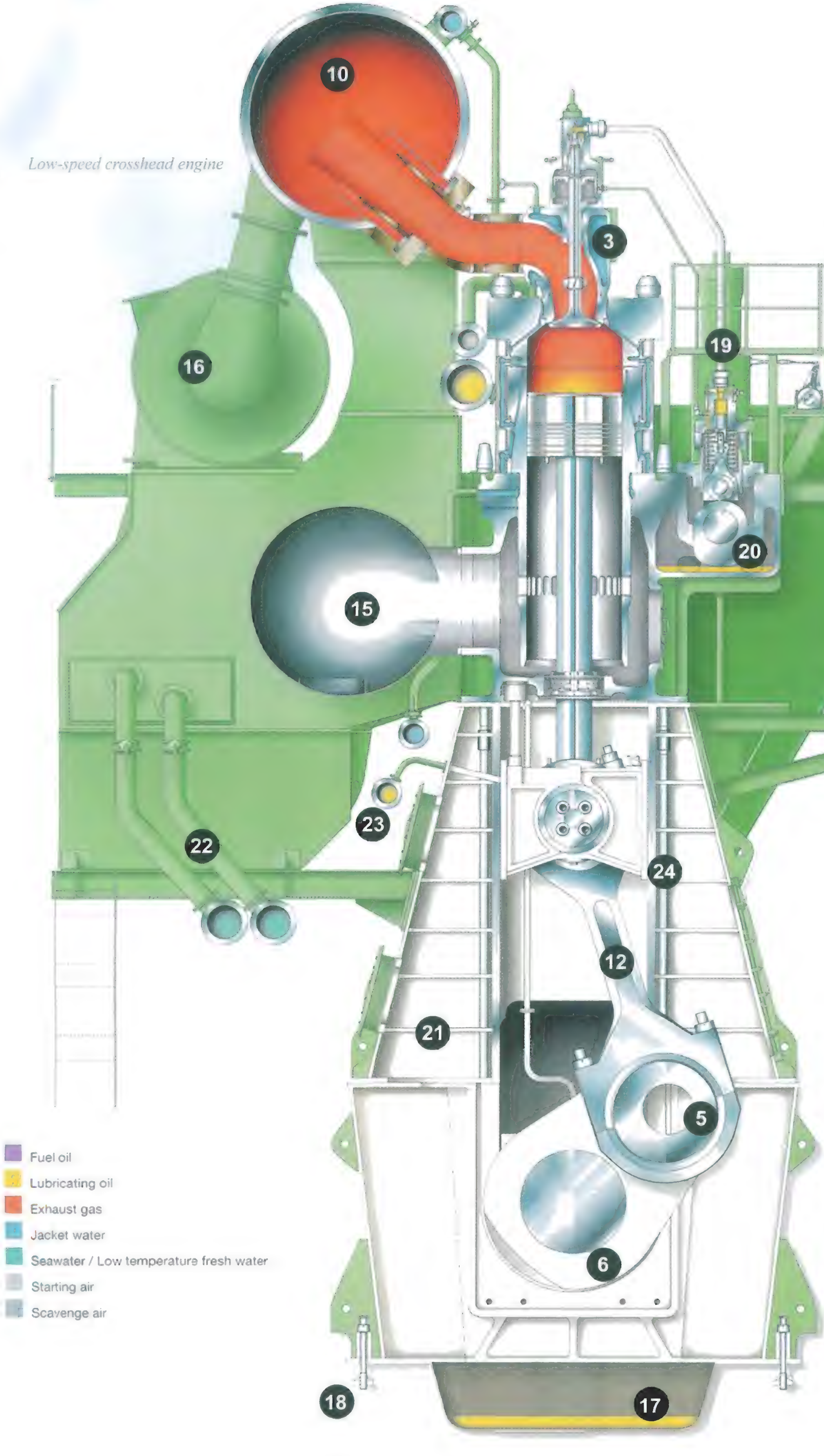




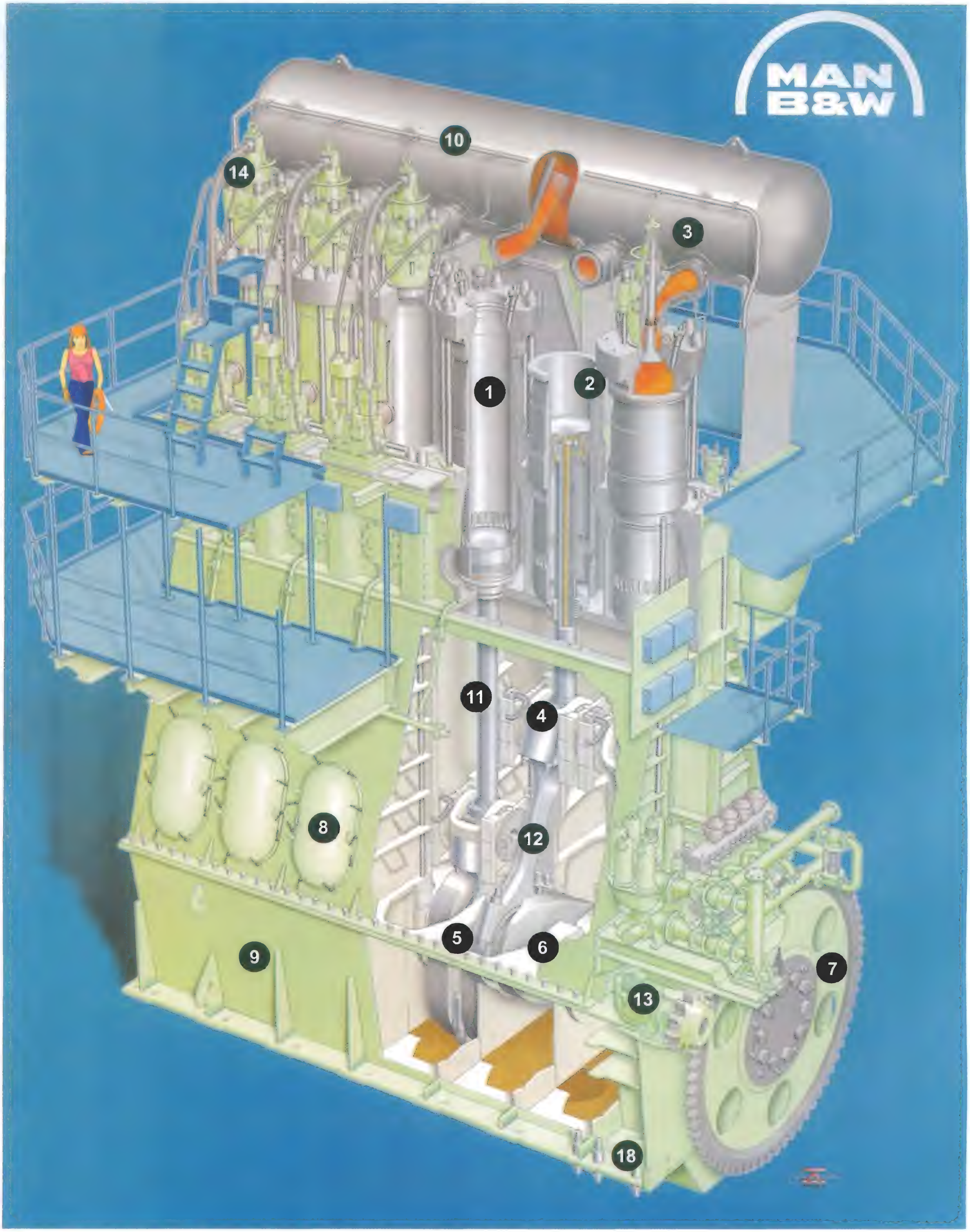
A ship's engine room is complete, compact and complex. Compressed in the smallest possible space are the a propulsion engine, shafting, electrical power plant, heating and cooling facility for the accommodation, fuel processing equipment, heating for fuel, water, etc. sewage treatment equipment, drinking water factory, ballast pumping station, cooling water pumps and lines, compressor station, fire-fighting pumps and distribution system.
The equipment is fully independent of outside resources.
Included, are the tanks with the necessary fuel(s), lubricating oil drinking water storage, rough water, dirty waste water, all kind of storage tanks, chemicals, high pressure air tanks, coolers, heaters, and an enormous length of piping for all the different systems, each with their valves, specific diameter and path to the required location. And, of course, the compulsory spare parts.

With the help of computers, each system in the engine room is displayed in 3-D drawings. In the past huge and complicated mock-ups were built to see if there was sufficient room for a certain piece of equipment.
With the computer model, an imaginary walk can be taken through the model, to test wether the accessibility of valves, manual handling gear, etc. is adequate.

The pipelines each have their own color.
Ballast water – blue,
Bilge piping – yellow,
Cooling water (salt) – red,
Fire-fighting (salt) - red
Lubricating oil – brown,
Fuel – purple,
Thermal oil – Rose



1. Cylinder
2. Piston
3. Exhaust valve
4. Crosshead bearing
5. Crankpin bearing
6. Crankshaft
7. Flywheel
8. Crankcase door
9. Crankcase bed
10. Exhaust gas receiver
11. Piston rod
12. Connecting rod
13. Turning gear
14. Cylinder cover
15. Air receiver
16. Turbo-charger
17. Sump
18. Foundation bolt
19. Fuel pump
20. Camshaft
21. A-frame
22. Cooling water (air cooler)
23. Lub. oil lines
24. Tie rod


MAN
B&W
10
14
3
2
1
11
4
8
12
5
6
9
7
13
18

1.2 Engine types

A ship's diesel engines can be two-stroke or four-stroke.
Two-stroke means that it takes two movements of the piston, down and up, to complete one combustion process.
With four-stroke engines, it takes four strokes.

Two-stroke engine:
1. Piston moves down. Air is taken in at the bottom of the cylinder.
2. Piston moves up. Air is compressed by the piston. Simultaneously, exhaust gasses are forced out through a valve(s) at the top of the cylinder. Fuel is injected and combustion takes place.

Four-stroke engine:
1. Piston moves down. Air is taken in through valves at the top of the cylinder.
2. Piston moves up. Air is compressed. Fuel is injected and combustion takes place.
3. Piston moves down.
4. Piston moves up. Exhaust gasses are forced out of the cylinder through valves at the top.

Two stroke engines are always line engines. Four stroke engines can be line engines or V-engines.

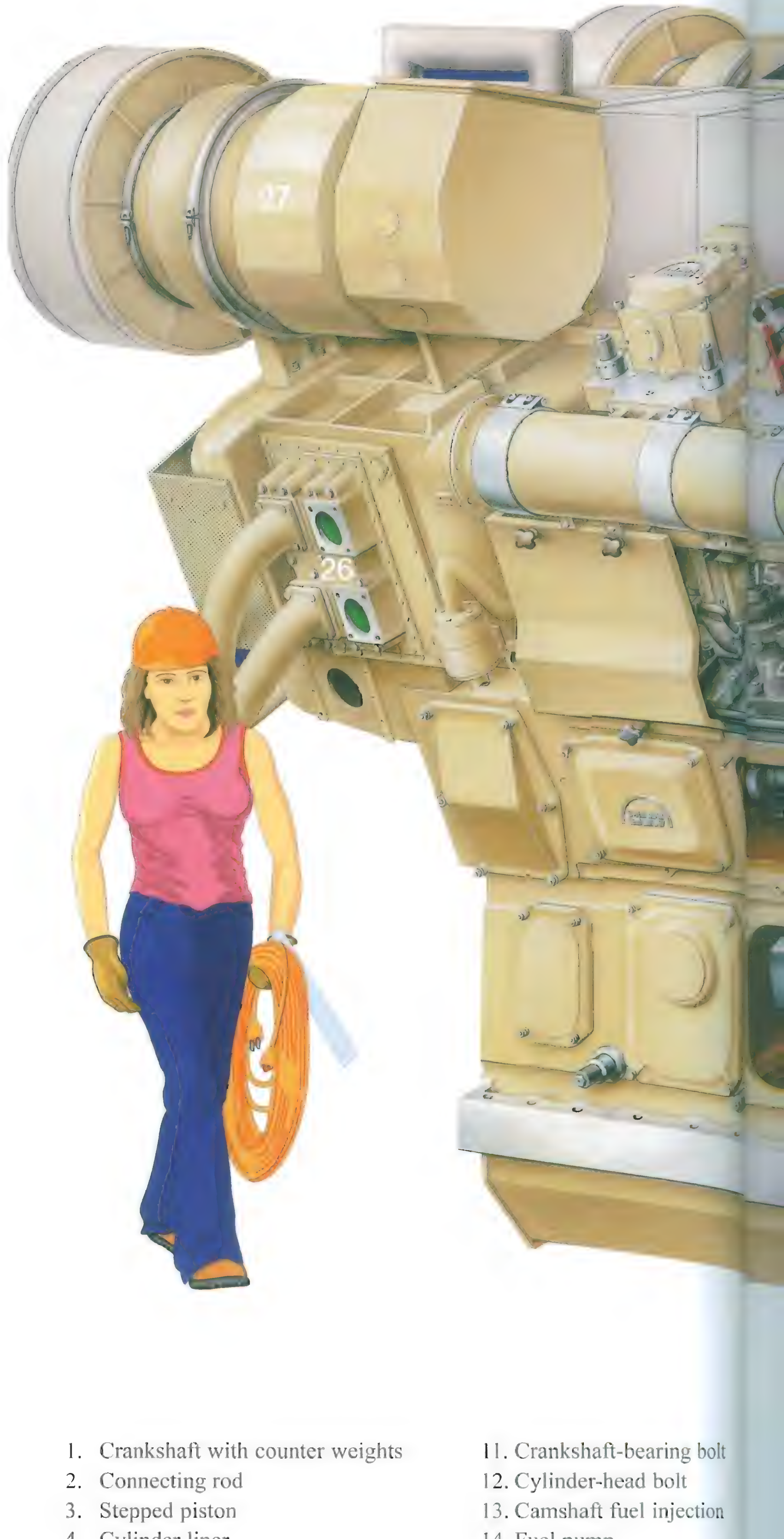
Line engine - the cylinders are placed in line next to each other.
V- engine - the cylinders are placed opposite to each other at an angle of 45 till 90 degrees from the vertical (like a V).

A 12-cylinder V-engine is the lenght of a 6-cylinder engine.
A 12-cylinder V-engine is cheaper than two 6-cylinder line engines. Line engines have a maximum of 12 cylinders, V-engines up to 20.

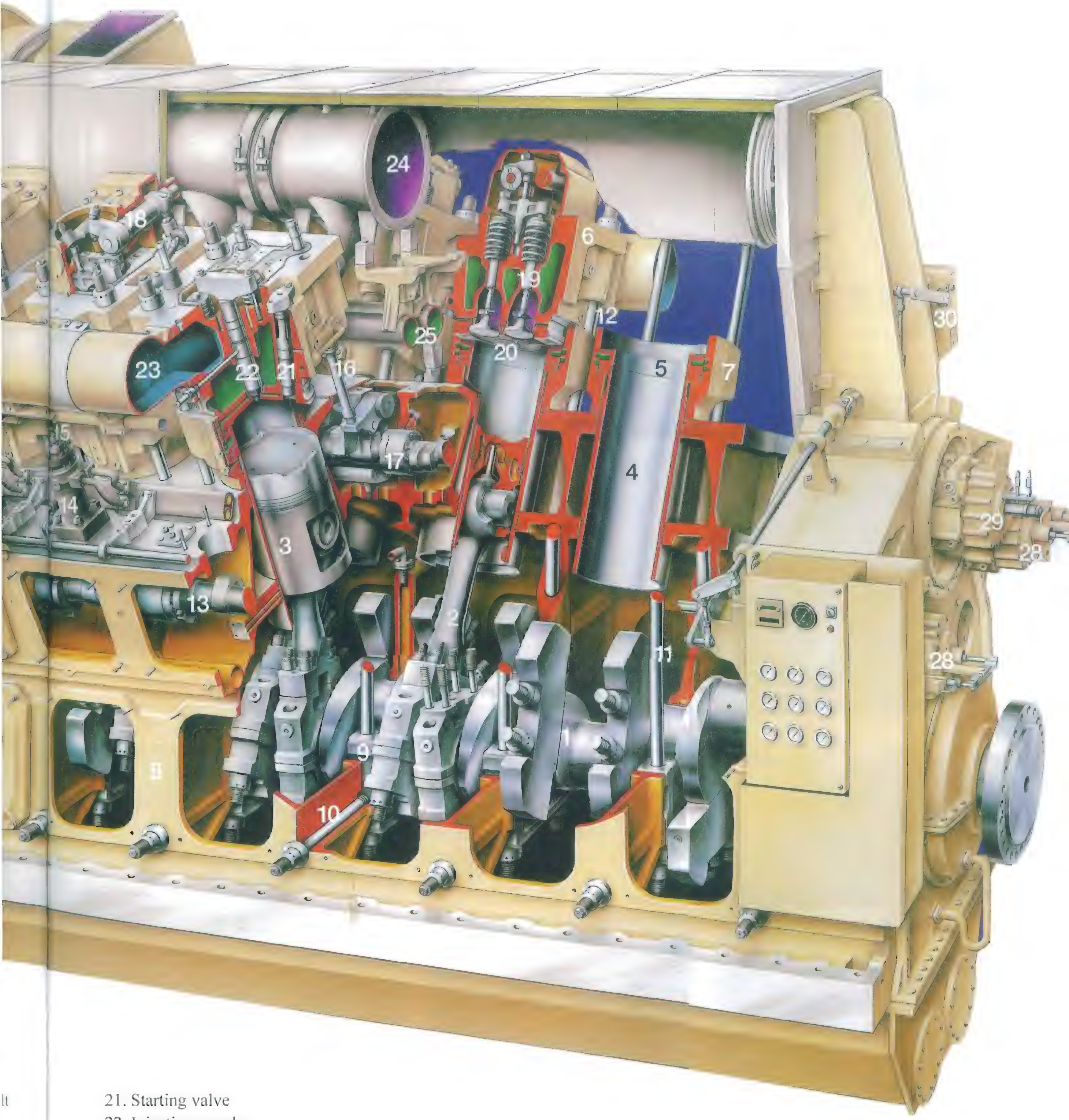
Furthermore, ship's engines can be characterised by their speed:

High-speed four-stroke engines - RPMs above 960.
Medium-speed four-stroke engines - RPMs ranging from 240-960
Low-speed two-stroke engines - RPMs below 240.

The high-speed and medium-speed engines drive the propeller after being reduced in speed in a reduction gear box. The low-speed engine is directly coupled to the propeller.



1. Crankshaft with counter weights
2. Connecting rod
3. Stepped piston
4. Cylinder liner
5. Fire ring with jet cooling
6. Cylinder head
7. Individual cylinder jacket
8. Cylinder crankcase
9. Crankshaft-bearing cover
10. Lateral crankshaft-bearing bolt
11. Crankshaft-bearing bolt
12. Cylinder-head bolt
13. Camshaft fuel injection
14. Fuel pump
15. Fuel injection pipe
16. Push rod
17. Camshaft valve control
18. Rocker arm
19. Exhaust valve with propell
20. Inlet valve

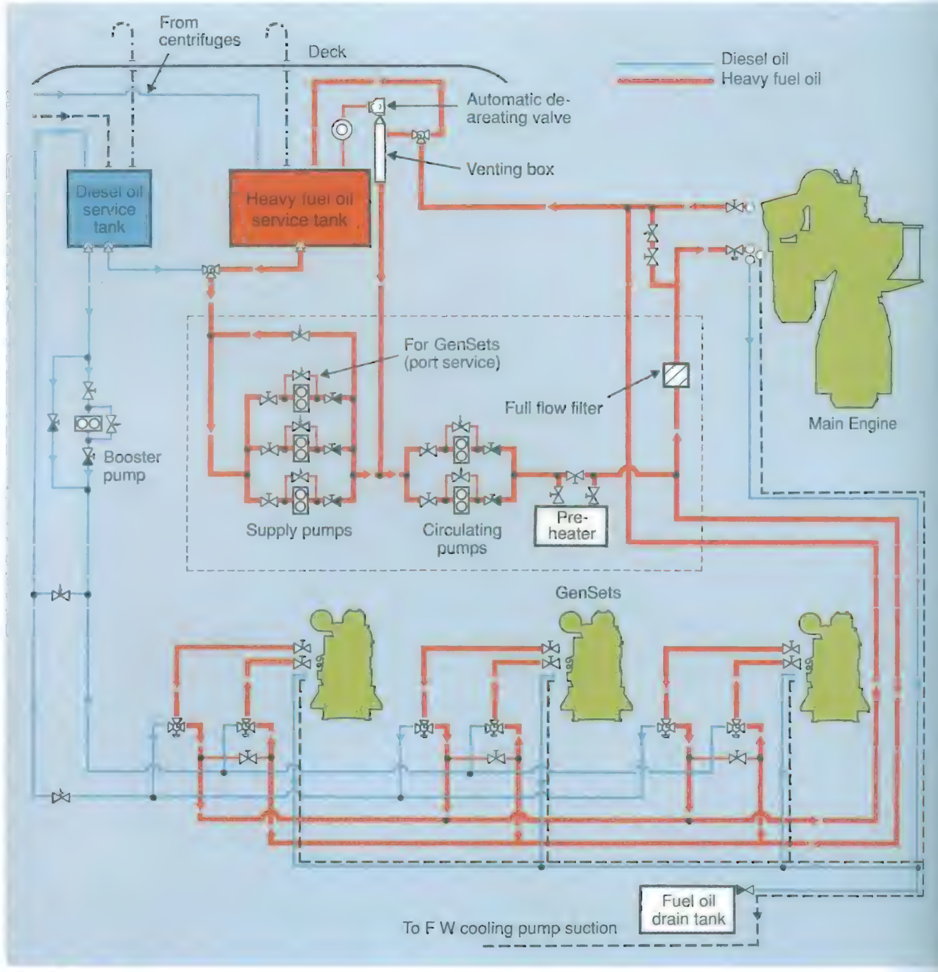


Medium-speed V-engine

21. Starting valve
22. Injection nozzle
23. Charging air pipe
24. Exhaust gas pipe
25. Cooling water pipes
26. Charging air cooler
27. Exhaust gas turbocharger
28. Adjusting device for injection timing
29. Adjusting device for valve timing
30. Governor actuator

1.3. Fuel

The criterion for the choice between engine types, apart from the size of the ship, available space and required power, is the fuel which can be used. **Diesel oil** (MDO) is best, produces least dirt, but is expensive. The so-called **heavy fuel** (HFO) is much cheaper, but requires additional systems, such as pre-cleaning and heating. It also produces sludge and dirtier exhaust gases. It contains more sulfur than diesel oil. This heavy fuel can only be used in medium-speed and slow running engines. High-speed engines require high quality diesel oil.



Fuel system

Fuel pumps

Purifier

The heavy fuel has a **higher viscosity** and cannot be pressed through injectors without treatment. It needs heating to decrease the viscosity and purifying to eliminate water and dirt particles too big to pass the injectors. Heating is done in fuel heaters, mostly by electric heating. The cleaning is done in separators, centrifuges where water and the heavy particles are separated from the oil.

Fuel manifold on a large container ship

The fuel is stored on board in tanks, the bunkers; in cargo ships, often in the double bottom tanks. Fuel is normally supplied through a hose by a bunker boat, straight into the ship's tanks. From the tanks it is pumped to a smaller tank in the engine room, the settling tank, a high, vertical tank, where water and heavy dirt sinks down. Via high suction, the oil is pumped through the separators to the day tank, the clean-oil tank. The water and dirt go straight to the sludge tank.
From the clean-oil tank the fuel is pumped by the low pressure fuel pump to the high pressure (HP) fuel pump which pumps it to the injectors. There is one HP pump per cylinder. Surplus oil, depending on the demands of the engine, flows back to the day tank.

The dirt from the separators goes to the sludge tank, to be disposed of ashore or by an incinerator.

The newer diesel engines have a so-called **common rail fuel system**.
A high pressure fuel pump keeps a piece of pipe at the injection pressure, and between that pipe and the injectors an electrically opened and closed valve is installed.
Opening and closing is regulated through a computer, which allows for adjustments to fuel quantity and timing per cylinder.

1.4 Cooling

All diesel engines produce heat and need cooling. This can be achieved by air cooling, but more commonly is liquid (water) cooling. This can be done directly when the outboard cooling water is pumped in and via a filter passes the engine and is again pumped overboard. This is used in very small ships only and only when the ship is in fresh water.

The bigger ships use a **closed-circuit** cooling system with water containing inhibitors, to protect the diesel engine against corrosion. The cooling liquid is then cooled in a heat-exchanger outside the diesel engine. The cooling medium is seawater, passing through a filter and heat exchanger, finally being pumped overboard. A separate seawater pump is then required. In small ships the heat exchanger can be installed in a sea chest which has natural circulation for seawater.

The cooler, pump, and often the filter are double installed with the necessary valves to enable maintenance and cleaning during operation.

Cooling water pumps

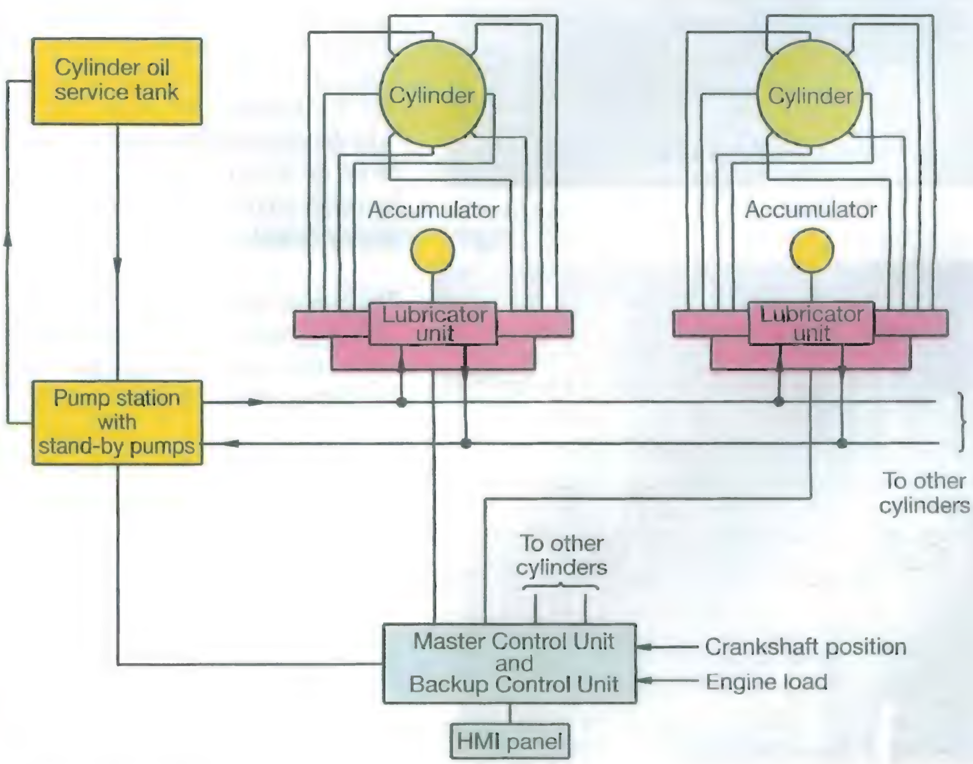
Cylinder lubricators

1.5 Lubrication

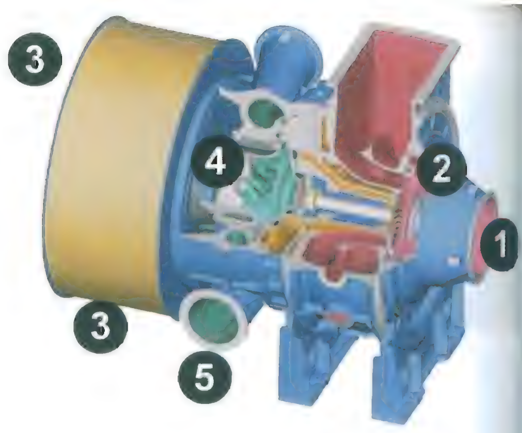
Each diesel engine needs lubrication. Normally this is done by pumping oil through the bearings and forcing this upwards from the crankcase towards the cylinder liners. Small engines have a built-in oil pump, larger engines have external pumps.

Oil is pumped through a filter into the engine. All the main bearings have their separate supply pipes. After use, the oil drips down into the crankcase, from where it falls into the main engine sump tank below the engine. From that tank it is pumped via an oil cooler and a filter system back to the engine. The quality of the **filtering** is critical for the engine's service life. The filter system can be complex. In a small engine it is only a filter, to be exchanged every so many hours. In big ships the oil is pumped through a very complicated micro-filter which has a built-in self-cleaning system via back-flushing. There are two parallel filters to avoid stopping the engine during filter change. The lubricating oil pump is mostly a **screw or gear-type pump**, where the output and pressure is constant, contrary to a centrifugal pump. Lubrication in large engines is much more complicated. The lubricating oil also has a cooling function, particularly for the pistons.

In large engines with a crosshead, these systems can be divided into crankcase lubrication, cylinder lubrication and cylinder oil cooling.



Cylinder lubrication--



1. Exhaust gas inlet
2. Exhaust as turbine
3. Air inlet filter
4. Rotary compressor
5. Compressed air outlet

1.6 Starting

Small engines are started using an electrically driven starting motor on batteries. The larger engines, however, are started using compressed air released in the cylinders, through the startingair valves on the cylinder heads, in the same sequence as the combustion sequence. The main air line from air vessel to engine contains a distributor, a rotating disc with holes, driven by the engine crankshaft, leading air to the appropriate cylinder.
When the engine is turns, fuel is injected, and the air injection can be stopped. The compressed air is held in compressed air vessels and kept under pressure and refilled by air compressors. The required pressure is approximately 25 bar.

Starting air receivers with main stop valve

Starting air compressors

1.7 Exhaust gas

The combustion produces exhaust gas. This is a very hot mix of carbon dioxide, nitrogen oxides, un-burnt fuel, surplus oxygen, sulfur dioxide, and carbon (soot). The sulfur oxides are harmful. With water, they form acids, corrosive to the steel exhaust pipes, and are not environmentally friendly. This of course also counts for carbon dioxide, and the nitrogen oxides. Pressure is put on reduction of N0-x and S0-x.

The heat in the exhaust gas can be used to warm up fuel and other purposes, such as accommodation heating. In the exhaust gas pipe a heat exchanger can be built in through which water or another liquid is pumped. When the liquid is water and it evaporates, the heat exchanger is called an **exhaust gas boiler.** When it does not evaporate, the heater is called an **exhaust gas economizer.**

1.8 Combustion air

The air needed in the cylinders for combustion is normally drawn from the engine room. In small ships an opening to the atmosphere is sufficient. In big ships, electrically driven ventilators supply the engine room with a large quantity of air to keep the engine room temperature sufficiently low. The performance of the engine can be **boosted** by supplying the cylinder with air of a higher pressure. More air means that more fuel can be burnt. And that again means more engine output.

The output of the engine is limited by the temperature of the exhaust gas. When the temperature in the cylinder becomes too high, damage can occur to outlet valves, cylinders etc. Therefore the air must have a certain over-capacity for cooling purposes.
The quantity of air can be boosted further by compressing the air before it goes into the cylinder. The air can be compressed by using the velocity of the exhaust gas. In the exhaust gas line a turbine is fitted, driving a rotary compressor. The air rises in temperature due to the compression.

the density increases and even more air can be supplied to the cylinder.

Cooling water from the main system is used for this air cooling, as well as to cool the whole unit.

1.9 Shafting

The shafting arrangement transfers the torque produced by the engine to the propeller. In the common, most simple and reliable systems, this is a monobloc casting. Controllable pitch propellers are also quite common, but are more complex, expensive and vulnerable to failures. They have, however, the advantage of the optimal pitch needed for each speed and a constant RPM, which allows the use of a main engine driven shaft generator.
RPMs are also variable when a shaft generator is used in combination with a frequency converter. This allows the optimal combination of RPM and pitch.
Normally the shafting consists of one intermediate shaft and the tail shaft.
The **intermediate shaft** is needed to create access when the tail shaft needs to be withdrawn. The intermediate shaft is then laid aside. The system has a number of bearings - one or two bearings on the intermediate shaft and the bearings in the stern bush. The total number can vary depending on the length of the system and the weight of the shafts.
The aft-most shaft, the **tail shaft**, is supported by the **stern bearings**.

Main engine flywheel with intermediate shaft and main lubricating oil pumps, driven by electric motors

Shafting looking aft

These are located inside the after peak tank, out of sight. These bearings are part of the stern tube, which is completely filled with lubricating oil so that the tail shaft rotates in oil.

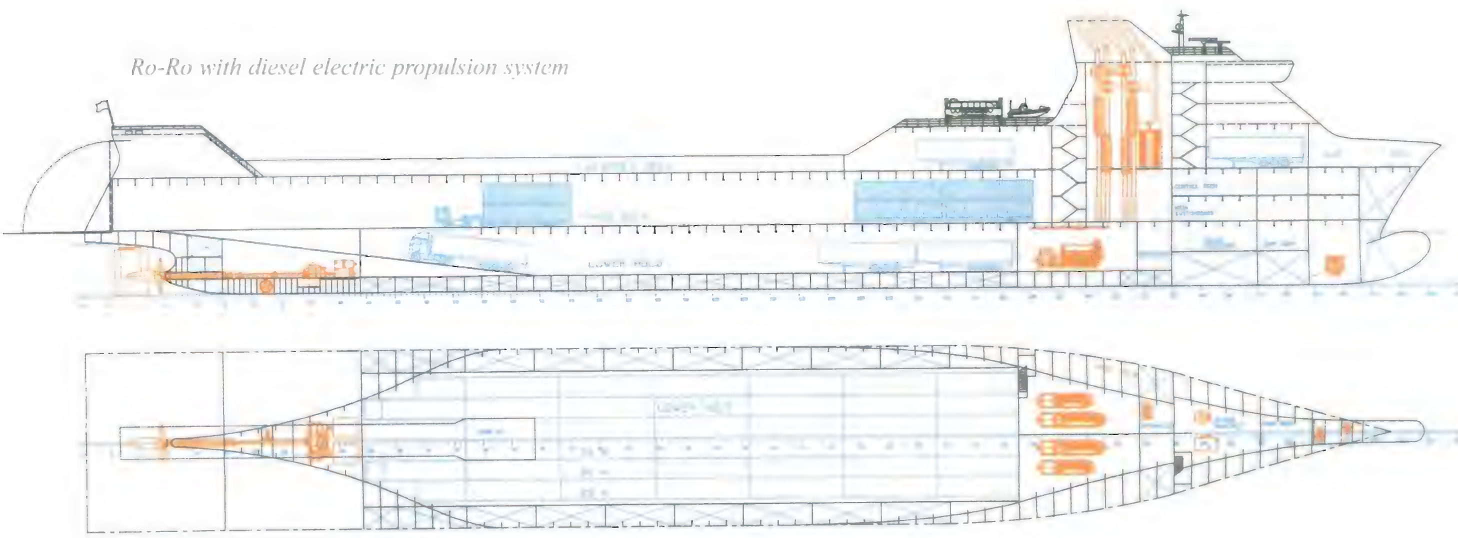
At the aft end of the stern tube a complicated **sealing system** is fitted, to keep seawater out and the oil inside the stern tube. This seal is located just forward of the propeller. The outer seal is protected by a surrounding ring, the rope guard. At the forward end of the stern tube, where the shaft exits the engine room a similar, but less complicated seal is fitted, again to retain the oil in the stern tube and preventing it from not leaking into the engine room.

The propeller is fitted on the tail shaft, normally with a press-on fit.
The after end of the tail shaft is conical, fitting the conical hole of the propeller precisely. Sometimes it is secured against turning by a key. But this method is outdated Nowadays, the **keyless fitting is normally used**, where the propeller is pressed on the conical surface by high oil-pressure.

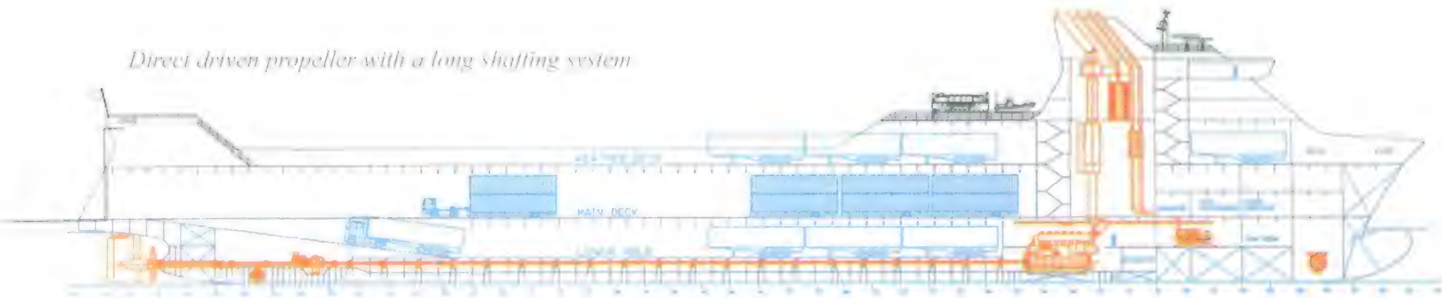
A controllable pitch propeller (CPP) is fitted with bolts on a flange at the after end of the tail shaft. Such a shaft has to be withdrawn outwards, which often makes removal of the rudder necessary. The shafting of a CPP is much more complex due to the hydraulic functions needed by the propeller, which are distributed through the hollow shafting.

A fixed pitch propeller is normally a right-handed propeller. A controllable pitch propeller is left-handed to create astern properties similar to those of a fixed pitch propeller.

Ro-Ro with diesel electric propulsion system



Direct driven propeller with a long shafting system



Gear boxes and Couplings

Reduction gearing is often needed between diesel engine and propeller, depending on the RPM of the diesel and the desired RPM of the propeller. This is usually a steel box, situated behind the diesel engine(s), with incoming driveshaft(s), each provided with teeth, which drive a larger wheel connected to the intermediate shaft.
The gearbox is partly filled with oil, and an internal pump sprays oil over the teeth.
The gears have various shapes - straight teeth, teeth under an angle or helical gears. The helical gears are often chosen for noise and vibration reasons, but are the most expensive type.
When a shaft generator is part of the installation, the gear box has provided with a power-take-off (PTO). Depending on the number of incoming and outgoing shafts, a gearbox can have various configurations.

Between shafts and generators, couplings are needed. When two main engines are used, one can be removed from the system for maintenance or, when a shaft generator is used, to generate power for that generator. The shaft generator then has a coupling.

For torsion vibration reasons, flexible elements are needed.
These can be separate or incorporated into the coupling.

1. Generator
2. Engine
3. Gear box
4. Shaft

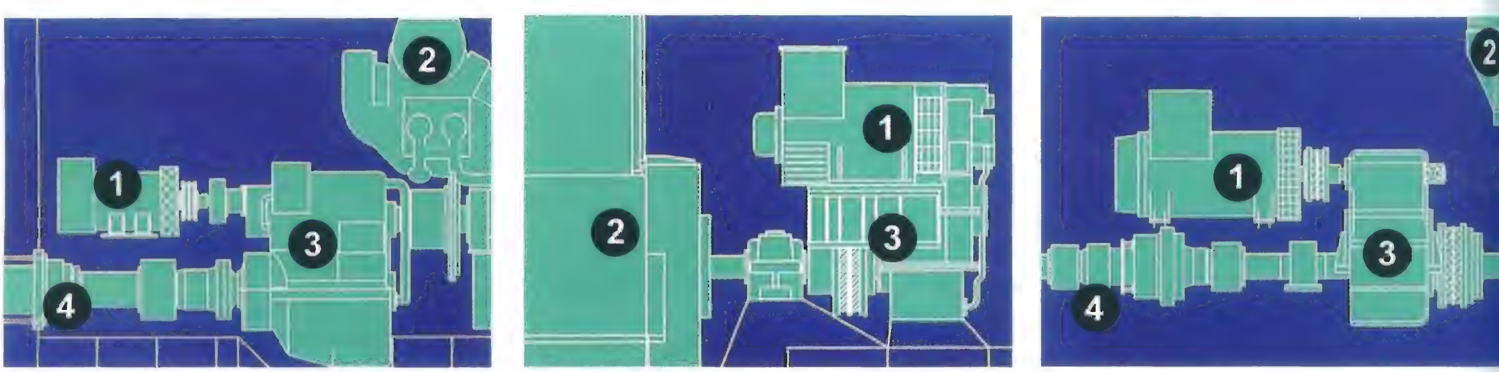
1.10 Electricity

A ship consumes considerable electrical power - steering gear, lighting, ventilation, pumps, compressors, airconditioning, etc. Diesel generators supply the power.

At least two diesel generators are needed. When one fails, the other can take over. To allow proper maintenance of one diesel generator when the ship is in normal operation, a third diesel generator is often used. All three are identical, and **each is capable of meeting the total electrical power demand at sea.**
The electricity produced is normally 3-phase current. When more than one generator is running the electric output can be connected through a circuit breaker to the bus-bars of the main switchboard in parallel mode.
A synchronizer panel is installed in the switchboard, only allowing the circuit breaker to be closed when the generator which is to be switched on, is in phase with the other generator(s) already running. Together, they feed one system.
The diesel output power is controlled by a governor on each diesel engine that regulates the fuel quantity while keeping the RPM constant.
Big ships usually have generators that produce 440 volt and 60 Hertz (3-phase).
A shaft-driven generator or PTO-generator (Power-Take-Off) is becoming popular, usually in combination with a controllable pitch propeller to ensure a constant RPM. The main engine produces the rotating energy, burning cheap heavy fuel instead of expensive diesel oil. Parallel running between the diesel generators and the shaft generator is normally only possible for a short period, i.e. the time to take over the load.
To ensure electric power for essential functions (navigation lights, steering gear, bridge equipment, lighting in engine room and accommodation, etc.) in case of a total electric power failure, a so-called black-out, ships are equipped with an emergency generator.
This generator feeds the emergency switchboard. It switches on automatically when this switchboard no longer receives power from the main switchboard.
Large main engines produce so much heat, that steam can be produced in an exhaust gas boiler to the extent that a **steam turbine generator** can supply the necessary electricity. A steam turbine then drives the alternator through a reduction gear box. This saves using a diesel generator and the necessary fuel.

Diesel generator

1. Diesel motor
2. Generator



Various methods of driving a shaft generator: the "power-take-off" or PTO

Such a system involves a complicated steam system of high quality, with the necessary safety devices, a condenser, circulating pumps, cooling water pumps, feed water and condensate pumps and accurate water treatment.
Electrical consumers are divided into two groups - essential and non-essential. In case of a power failure, the non-essential users are automatically switched off. Essential users, such as steering gear, main engine lube-oil, fuel and cooling water pumps, navigation lighting and bridge equipment, remain operational as long as possible.

Small boiler

Rotating piston steering gear

1.11 Heating

The heat produced by the engine is normally not sufficient for heating the ship, and the engine is not always running. Most ships therefore have a small **oil-fired boiler**, for accommodation heating and fuel heating. This oil-fired boiler can be combined with the exhaust gas boiler. Ordinary cargo ships can do with a small boiler.
Tankers generally have large boilers as they use steam to keep their cargo heated for pumping, and often have steam-driven cargo pumps for the discharge of their cargo.
In that case, the ballast pumps are also steam driven.
Instead of steam, other liquids, such as **thermal oil,** can be used for heat transfer.
The advantage is that the system is simple.
A disadvantage is that the oil is a fire hazard.

1.12 Heat exchangers

Heat is produced in various places and must be disposed of. On the other hand, liquids and air must be heated. Therefore, a number of heat exchangers are found in every engine room:

- **Fresh cooling water coolers -**
  - for cooling water
- **Fresh cooling water heaters -**
  - pre-warming of diesels
- **Lubricating-oil coolers -**
  - one for each auxiliary diesel engine, attached to the engine, two for the main engine
- **Air coolers -**
  - for combustion air
- **Air heaters -**
  - for general heating, air conditioning
- **Oil heaters -**
  - for fuel

Types of coolers:
Straight-tube coolers, U-tube coolers, Plate coolers

1.13 Pumps

Liquids are to be pumped through all the systems. For different media different pumps are used:
- For cooling water, normally centrifugal pumps - low pressure, large quantity
- For lubricating oil, screw type pumps - constant supply, constant pressure
- For boiler feed water - two or three stage centrifugal pumps or piston pumps
- For fire pumps - high-pressure centrifugal pumps
- For highly viscous fuels - gear type pumps
- For dirty water, etc. - piston pumps, membrane pumps

Centrifugal pumps

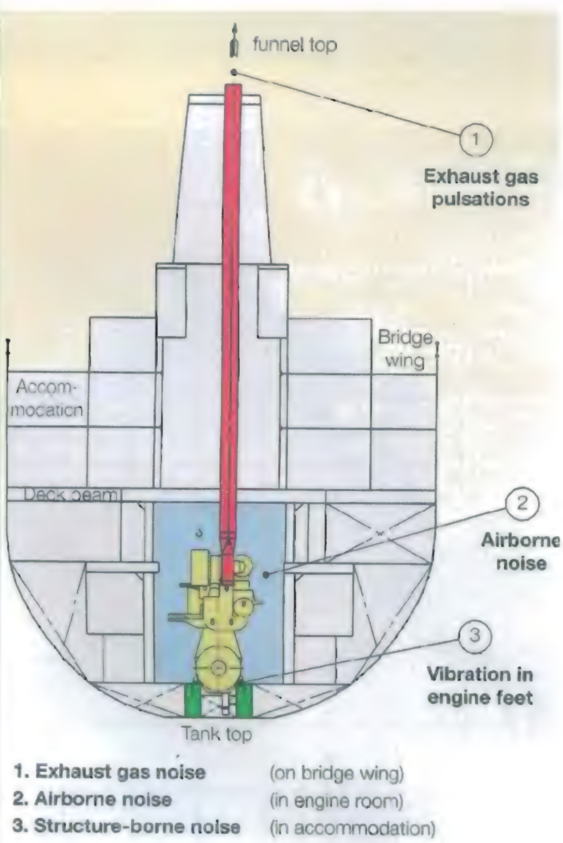
Small bilge pump of the bilge water separator

1.14 Safeguarding

The various machinery in the engine room is safeguarded by control systems. A simple diesel engine of 15 kW already has a lubricating-oil pressure alarm. When the lubricating-oil pressure is too low, a red light combined with a high, penetrating noise will draw attention. The bigger the engine, the more safeguards. For example there are alarms for: cooling water too hot, cooling water pressure low, lube-oil level low, return lub-oil temperature too high and so forth.

In a modern engine room, all these alarms are installed in a control room where problems can be seen on a screen, and remedial action can be taken, either manually or automatically.

When cooling water is too hot for instance, the flow can be increased by opening a regulating valve. When the water temperature is too low, that same valve can reduce the flow. When that remedy fails, an alarm will go off.



Vibration sources

1.15 Vibration and noise

Diesel engines produce vibration. Each combustion inside a cylinder produces a pulse conveyed via the foundation of the diesel engine into the ship.

The propeller is also a source of vibration. Firstly, the pressure field around the blades of the rotating propeller cause pressure variations on the aft ship above the propeller. Secondly, the blades, when rotating through their cycle, touch water with a different velocity at each location of that field.

These actions produce pulses:
- in the hull above the propeller(s)
- through the shafting and its bearings.

Each part of a ship has its own natural resonance frequency. When the pulses induced by some machinery match the resonance frequency of a ship's component, and the pulse is sufficiently strong, vibration is the result. Noise is generated by air and structure vibration. Main sources of air pulses are the exhaust system, combustion explosions and turbo chargers.

1.16 Fresh water

Ships navigating deep sea, make their own fresh water. Salt water, evaporated into steam and then brought into a condenser produces condensate, which is fresh water. When the pressure in the boiler is reduced below atmospheric, the boiling temperature is lower than 100°C. This phenomenon allows the hot cooling water, after having done its work in cooling the main engine, to make fresh water. The cooling water is led through a heat exchanger inside the lower part of a drum, where the pressure is reduced using an ejector. The heat exchanger is submerged in clean seawater, which boils in the low-pressure atmosphere. The vapor goes to the high part of the drum, where another heat ex-changer with cold seawater acts as a condenser. Condensate drips from the tubes. Below this condenser a conical dish collects condensate.

Through a drain line in the center of the dish, the fresh water is transferred outside the drum. This system is called an **evaporator.**

A second way of making fresh water is filtering. Salt water is pumped under high pressure through a membrane with openings so small that salt molecules cannot pass. The water passes and comes out as fresh water. This process is called **reverse osmosis.**

Reverse osmosis plant

Fresh water generator / evaporator

1.17 Start-up arrangement

In case of a total black-out, empty batteries and loss of starting air, the ship's crew must be able to start systems from zero. Usually the first build-up of power is done with a small air compressor driven by a manual start diesel, sometimes even a hand operated compressor, by which a small air vessel, capable of starting a diesel generator, can be brought under pressure. When that diesel is running and producing electric power, the systems can be activated one by one.

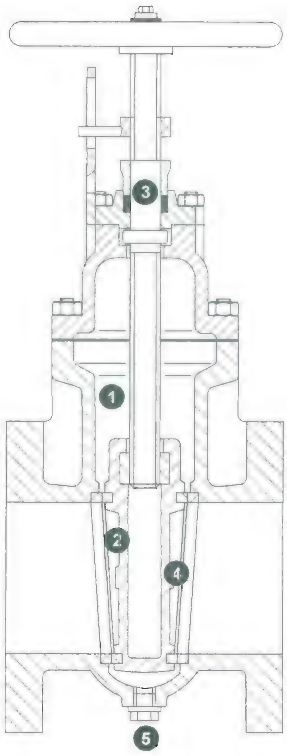
2. Valves

In ships, many pipeline systems are installed for the transport of various kinds of liquids, gases, and energy. In those systems valves are necessary and fitted in large numbers to stop or regulate flow, to connect numerous spaces or items to a system or to isolate the system from open air or outside connections.
The most common valve types are mentioned below.

2.1 Gate valves

A gate valve has a housing between two flanges where a wedge slides in and out, leaving the throughput completely open or closing the throughput completely or partially to restrict flow. The housing has sealing rings as seats for the wedge sides. The wedge also has a sealing ring at both sides, providing double sealing.
The bottom of the housing is often provided with a plug, allowing the tightness of the valve to be checked without opening it up. Materials for housing and wedge are cast iron, cast steel or bronze. The sealing rings are often bronze. Other variations are possible, depending on the type of liquid, possible galvanic action and fluid velocity.

Advantages:
- 100 % throughput
- two sealing surfaces
- short building length
- tightness control in situ



Gate valve

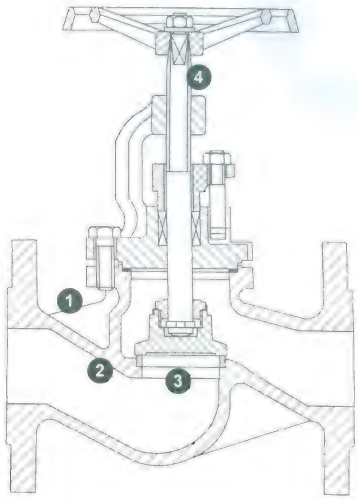
1. Housing
2. Wedge
3. Spindle
4. Sealing rings
5. Plug

Disadvantages:
- vertical dimensions, especially when fitted with a, hydraulic actuator
- weight

Additional strengthening is needed when used in high pressure systems. Used for cooling water, ballast water, bilge systems, cargo (oil) systems, fire lines, foam lines, etc.

2.2 Globe valve

A globe valve has a ball-shaped housing between two flanges, with a horizontal separation at mid-height, configured so that the upper and lower parts are open towards one flange each. There is a circular hole in the seperation that can be closed with a disc, which is moved up and down with a threaded spindle. When the disc is kept loose from the spindle, the globe valve acts as a non-return valve. Materials for housing and cover are cast iron, bronze, stainless steel, etc. Disc and seat may be of bronze or stainless steel. This depends on the type of liquid pumped.



Globe valve

1. Housing
2. Separation
3. Disc
4. Spindle

Advantages:
- easy maintenance
- easily adjustable flow
- non-return possibility

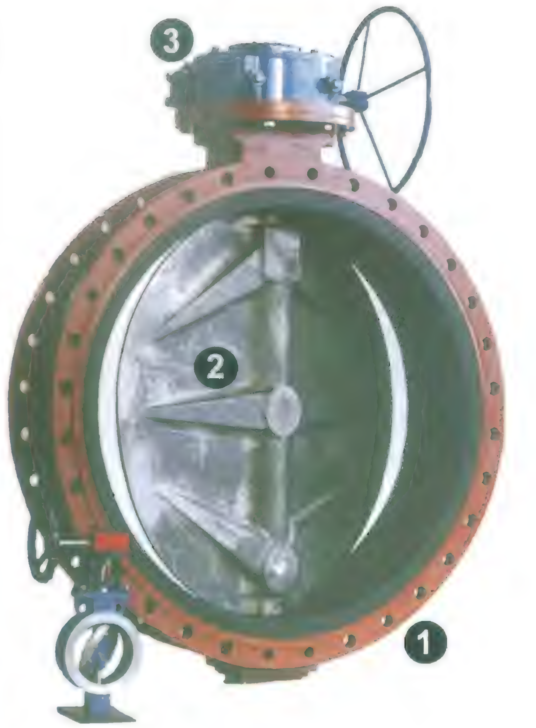
Disadvantages:
- restricted flow, turbulence
- remote control only manually (extended spindle).

Used for cooling water, steam, various clean-water systems,

2.3 Butterfly valve

A butterfly valve has a ring-shaped body, the diameter of the pipeline that it is used for. In the ring is a circular disc, which can be turned by a spindle. The ring is clamped between the flanges of the adjacent pipelines. The ring is provided with a rubber lining on the inside, forming a seat for the disc.
In open position, the flow is hardly restricted; the disc is positioned in the direction of the flow. By turning the disc 90° or nearly 90°, the disc is closes against the rubber lining of the ring. The rubber lining is vulcanized, or interchange-able. There are also types with a removable seat.

The rings are of cast steel or cast iron, disc of bronze, rubber lining of neoprene (oil resistant). Also fabri-cated with flanges on ring.



Butterfly valve, 1000 mm nominal diameter

1. Ring
2. Disc
3. Handle

Advantages:
- extremely short building length
- light
- nearly unrestricted flow
- simple actuator (only 90° movement)

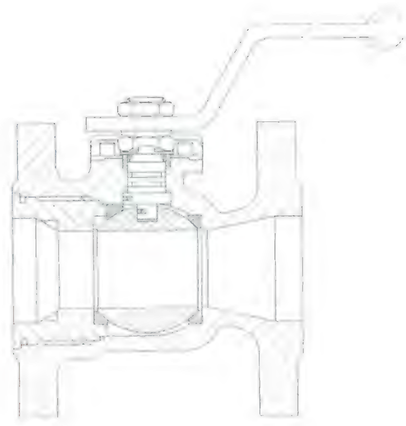
Disadvantages:
difficult flow regulation

Used for cooling water systems, sea water valves (overboards), cargo systems in VLCCs and ULCCs.

2.4 Ball valve

A ball valve has a ball-shaped housing between two flanges. At mid- length there is a dividing flange. Inside the housing is a seat ring for both flanges. A ball is fitted between the seats with a tubular hole in the center, stem upwards, for rotation of the ball, max. 90°. The flow is regulated by partial rotation of the ball. The materials depend on use, but the ball is usually stainless steel. It is used primarily for chemicals.

Advantages:
- double seal
- unrestricted flow when completely open, no turbulence



Ball valve

Disadvantages:
- expensive
- heavy
- difficult adjustment of both seals.

Apart from the above valve types there are numerous variations on the main types:

- Needle valves for accurate flow regulation are a variation of a globe valve.
- Spring-loaded valves are valves which can be closed by a remotely triggered spring. They are basically like globe valves.
  Safety valves which open at a pressure higher than desired against a spring, are also globe valves.
- Spade valves are gate valves with a flat closing spade.
  Non-return valves exist in numerous forms:
  - swing check-valves in the discharge of a cargo pump
  - globe valves with loose disc in cooling systems
  - weight loaded swing check valves in inert gas systems, etc.

3. Bilge line arrangement

Bilge pumps keep the engine room dry. There are normally three systems. First, a **small pump** capable of dealing with the normal small, daily quantities. This small pump pumps the dirty water (water and oil) into a bilge holding tank.
From that tank, the water is pumped by another small pump through an oil-water separator overboard, only when it is sufficiently clean. If not, it goes to another storage tank, the sludge tank.

A **second, bigger pump,** can pump the bilge water from the engine room straight overboard, but this is only allowed in emergencies.

A **third** possibility is to use the **direct suction** of the main cooling water pumps, which has huge capacity for big leaks in emergencies.

The bilge line arrangement is an important safety system that is required by law. The purpose of the bilge line arrangement is to pump excess water out of the ship.

Rules made up by governments and Classification Societies have to comply with international SOLAS-rules. SOLAS states that the bilge line ballast line and fire-fighting systems must be three independent systems that can take over the work of the others if necessary.

Small amounts of water can accumulate in the ship as a result of condensation, leakages of pipes, results from washing or rain, especially in "open ships".

Condensation can occur when warm air hits a cold surface. In the most favorable circumstances the water flows down the sides into the bilge well and can be pumped overboard. When the water remains on (relatively cold) cargo or seeps into the cargo, damage to the cargo may occur.

Ships without hatch covers, or "open ships" have to have additional pump capacity in the bilge line arrangement to remove incoming seawater or rain (SOLAS art 59 sub 2).

As soon as the holds are emptied and cleaned, the bilge line arrangement has to be tested. When it has been found in order, this is noted in the ship's journal. For some kinds of dangerous goods, the bilge arrangement has to be capable of pumping bilge water from any individual cargo hold. The dangerous goods have to be kept separated.
Certification determines what kind of dangerous goods may be transported by a ship.

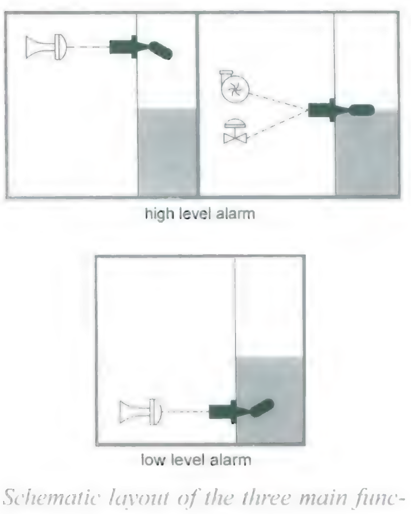
The pump capacity of the bilge pump is between 100 and 300 m³/hour. A hole in the side of the ship 5 meters below the water line means that a certain capacity, depending on the size of the hole is needed to remove the amount of incoming water. The formula to determine the capacity needed is:

$$V = a \times \sqrt{2 \times G \times D}$$

V = volume in m^3/s incoming water
a = area of the hole in m^2
D = depth of the hole below the surface
G = Gravity (9.81)

In the example this means that a hole of 5 * 5 cm makes up for 90 m^3/hour and a hole twice that size (7.1 * 7.1 cm) produces 180 m^3 water/hour flowing into the ship.

The valve in the bilge well (in the engine room) must be fitted with a safety device to ensure that dangerous goods cannot accidentally pass into the environment or inside the ship.
To determine the amount of fluid inside a bilge well or a ballast tank one of two systems has to be present:
- Manual - sounding with sounding tape using a sounding pipe that ends in a tank or a bilge well to measure the height of the fluid.
  Remote measuring system - the fluid level can be read from an indicator in the engine room (remote control). A float is placed in the bilge well and when the fluid level rises, so does the float. When the float reaches a certain level, an alarm is activated.



Schematic layout of the three main functions of magnetic float switches

As soon as the alarm in the bilge well is activated, the bilge alarm on the alarm panel in the engine room is activated as well. With an unmanned engine room the engineer on watch is alerted. The water levels in ballast tanks are often measured using bubble-pipes. The pressure needed to blow air to the bottom, against the water-pressure, is picked up by a transmitter. The signal is displayed in the cargo control room.

The bilge line arrangement consists of the following parts:

3.1 Bilge pumps

These pumps have to be available for immediate use. However, they may also be used for other purposes according to the regulations.
A bilge pump must be self-priming. This means that it does not need help drawing water from the intended compartment.

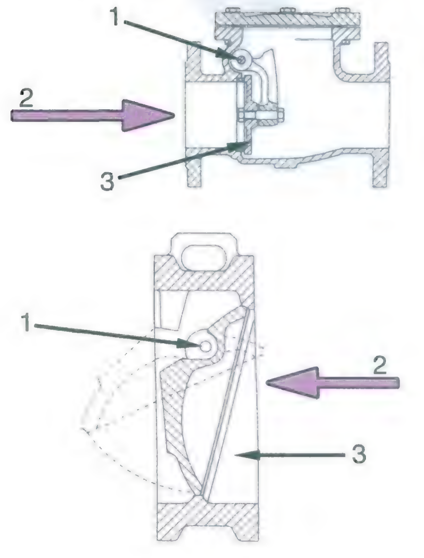
3.2 Mountings (fittings)

Mountings are ordinary valves, safety valves, plugs, filters, distributors, etc. Several suction lines are mounted on a manifold. The suction lines are fitted with valves to open or close the lines. To keep the capacity as high as possible, one valve at a time is should be opened. When more valves are opened at the same time, the suction capacity in the well is reduced. Check valves are used as non-return valves.

Example:
The liquid removed from a bilge well must not be allowed to flow back to that bilge well. A non-return valve is placed in the suction line.

The manifold is a cast iron housing, with bronze seats, valve lids and spindles. Bronze is seawater resistant.

1. Hinge point
2. Direction of flow
3. Closed valve
   (dotted lines indicates open valve)



Two types of non-return valves.

3.3 Main Bilge Line

The main bilge line is situated in the engine room and runs from the manifold to the suction side of the pumps. The suction lines run from the manifold to the connected compartments. The main bilge line is usually made of galvanized steel. The bilge arrangement in the engine room consists of one (compulsory) direct system and one indirect system. The indirect system operates through a manifold.

3.4 Suction Lines

The cargo holds are provided with 4 bilge wells, one in each corner of the hold. They are each provided with their own suction line to the main line. In which well the water is collected depends on list and trim.

3.5 Bilge Well

A bilge well has two compartments, separated by a bulkhead that extends half or three quarters of the height of the well. A lid with small holes covers the well. As soon as the water reaches a certain height, it flows to the well next to it. The suction part of the bilge line is situated in that part of the well.

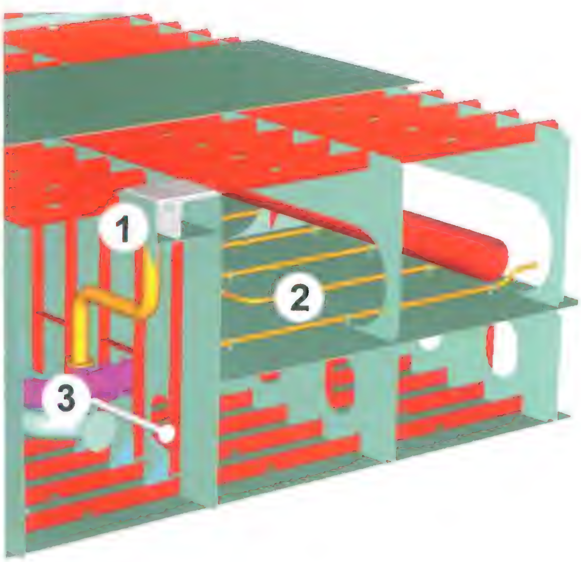
This suction side of the main cooling water pumps has a free suction. In case of a major leak, this enables the large capacity of the cooling water pump to be used as an emergency bilge pump. This is called emergency suction. The valve is manually operated, with a large diameter red handwheel above the floor plates.

3.6 Ejector

An ejector creates a vacuum by the speed of the water flowing through it. This is also a possibility for pumping bilges, for instance in chain-lockers. The pressure of the water flowing through the ejector is created by the fire-fighting pump, which can build up higher pressure than the bilge and ballast pumps. The bilge water goes overboard together with the driving water.

3.7 Bilge water cleaner/separator.

According to the MARPOL Convention bilge water from the engine room cannot be pumped overboard. All bilge water from engine / machinery spaces, has to go through a separator to separate any oil from the water. The water can, under certain circumstances, be pumped overboard. The oil goes to a dirty-oil tank. This separator, with an oil-content-meter and alarm, is compulsory for ships of more than 1000 GT. The water pumped overboard may not exceed 15 ppm (parts per million) oil. (see Chapter 6, Regulations/Marpol)



1. Bilge well
2. Heating coils
3. Bilge line

1. When an ordinary valve is opened by lifting the lid, the water can flow in both directions.
2. When a screw down non-return valve is opened, i.e. the spindle turned anti-clockwise to allow the lid to open, the water can flow from below the lid to above, and not in the other direction.

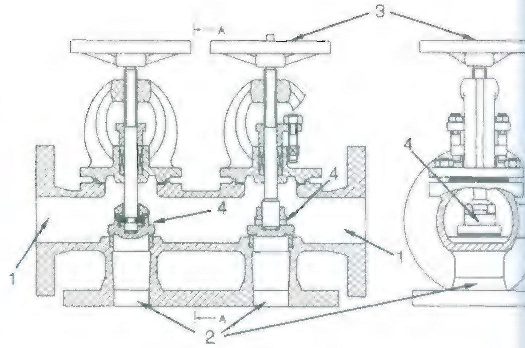
4. The ballast arrangement

The ballast system is used to pump seawater (weight) in or out of the ballast tanks. The rules for the ballast system are less stringent than the rules for bilge systems.

Reasons for taking ballast on board or shifting ballast once it is on board are:
- to improve stability of the ship, especially when the ship does not carry cargo
- to get the ship deeper in the water, to improve sea-keeping.
- to alter the trim
- to reduce bending moments or shear forces
- to control the list during loading and discharge. Many ships use an anti-heeling system for this purpose
- to improve maneuvrability.

An **anti-heeling system** is used to minimize the list (in port). Pumps with a large capacity (1000 m^3/hour) are installed between two tanks (one port side and one starboard). These pumps can transfer water from one tank to the other at great speed. The system is fully automatic and much used on ships with cranes, container vessels and Ro-Ro vessels to reduce the list that can occur during cargo handling.

Fore and aft peak tanks, deep tanks, double bottom tanks, and wing tanks are usually used for ballast water. All depending on the ship's type. Bulk carriers often use one of the holds for ballast, during a ballast voyage.



Distributor that can be fitted with non-return valves (bilge arrangement) or stop valves (ballast arrangement).

1. Suction of the pump
2. Suction from the bilge well
3. Hand wheel to operate the valve
4. Stop valve

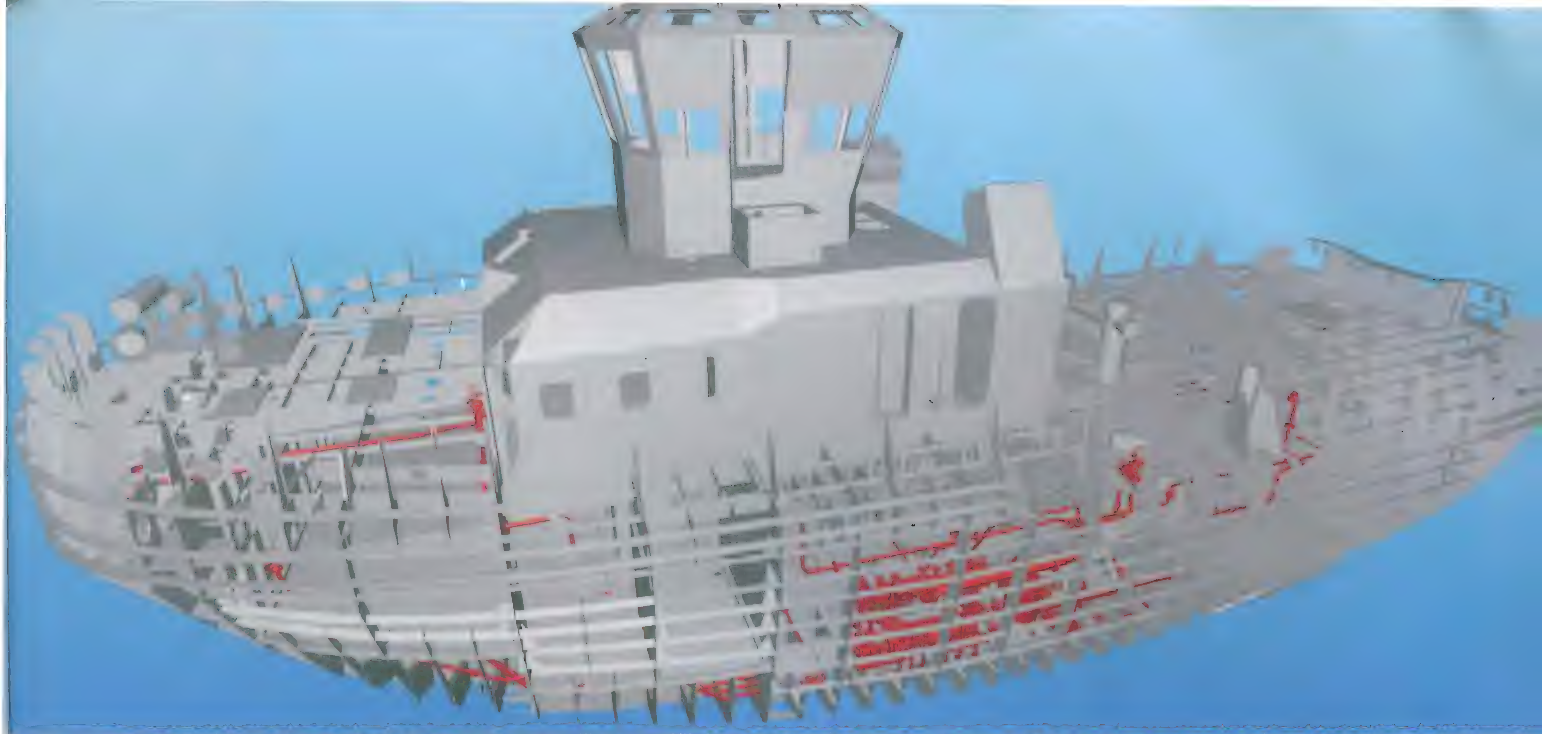
An advantage of using ballast instead of fuel in the double bottom is that welding is allowed on the tank top.

The designer determines the ballast capacity to meet minimum operation draft requirements imposed by Class / IMO. The duration of the voyage and the purpose of the ship is taken into account when deciding on the available space for ballast and the capacity of the ballast pumps.

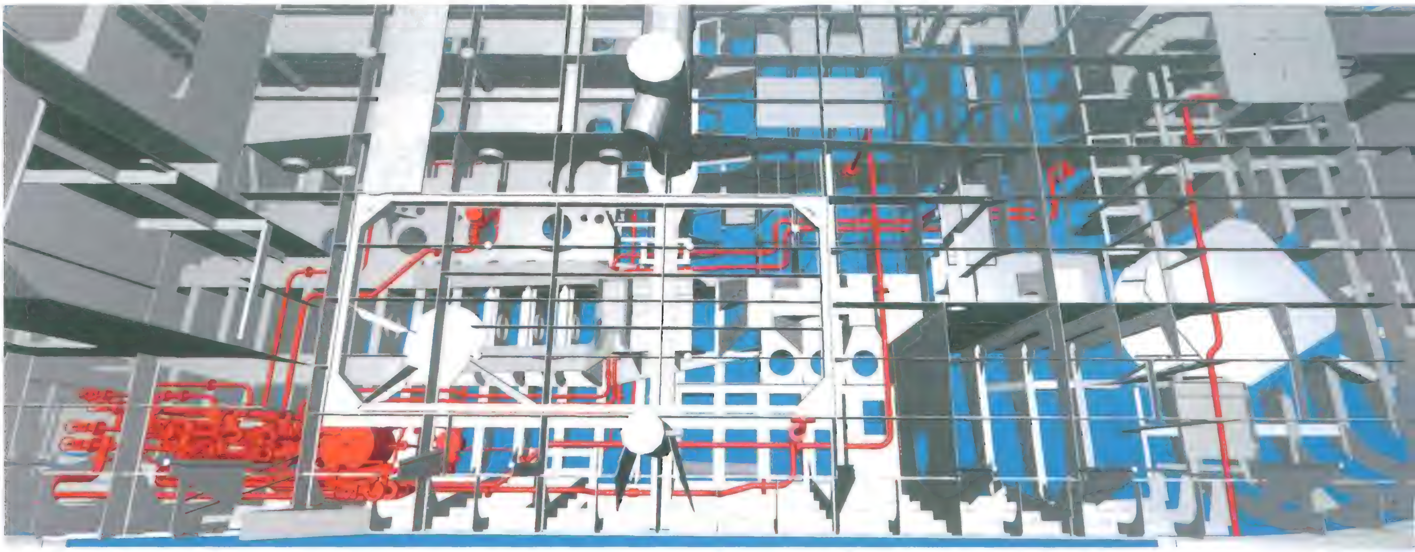
In small ships, the ballast pumps are usually suitable as bilge pumps. This makes the ballast system an integrated part of the bilge arrangement, to the extent that a ballast pump may even serve as main bilge pump.

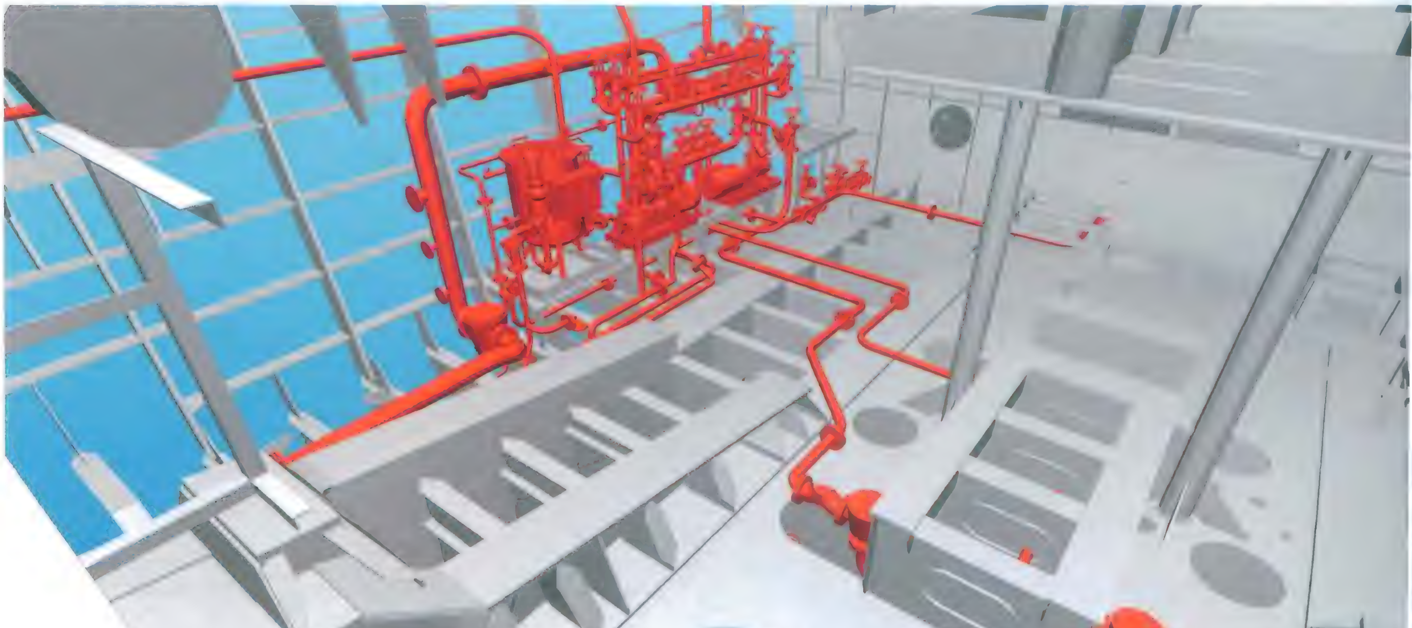
Contrary to the valves in the bilge arrangement, the valves in the ballast arrangement have to be two-way valves as the tanks must be able to be filled and emptied. Double bottom tanks, and to a lesser extent in multipurpose ships, the wing-tanks can be filled directly from outside through the sea inlet, without using the pump. Nowadays the ballast system is often designed as a ring line. Remote controlled valves are used to empty or fill the ballast tanks.

Ballast lines inside the double bottom may be made of synthetics. The bulkhead passages have to be steel for fire safety.



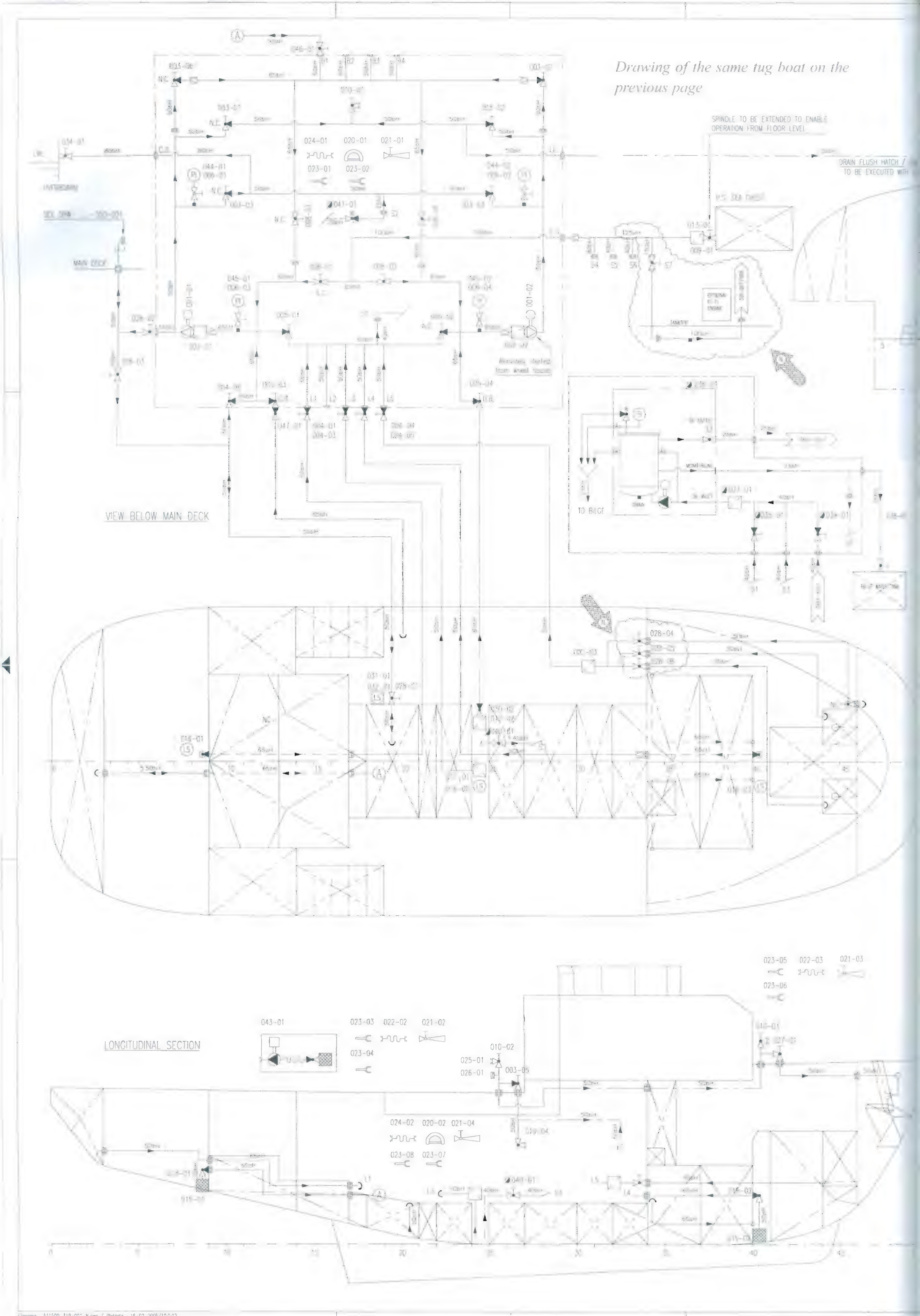
The bilge line system of a harbor tug boat. The pictures show the bilge lines. The pictures also show stiffening and construction parts of the engine room.

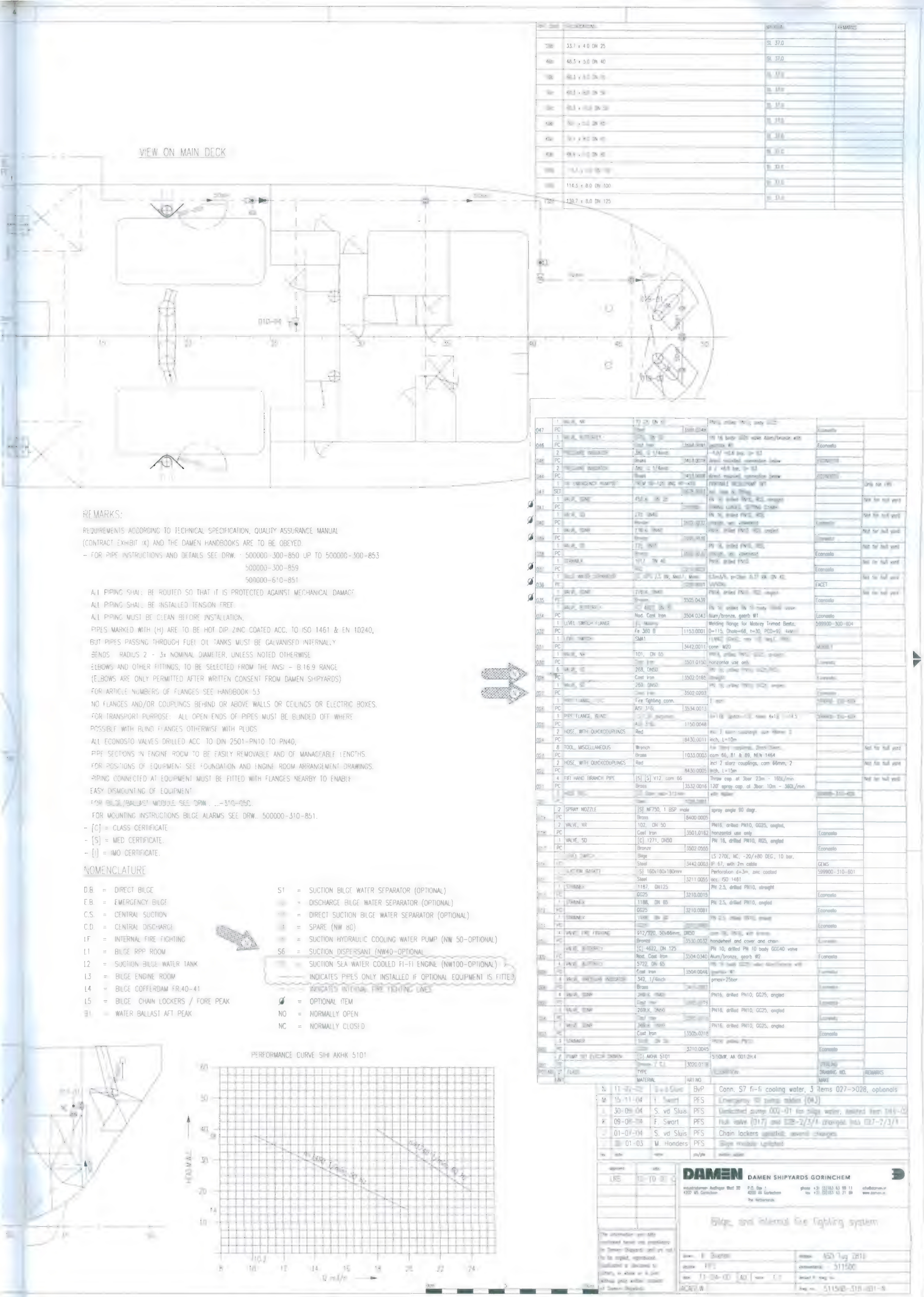




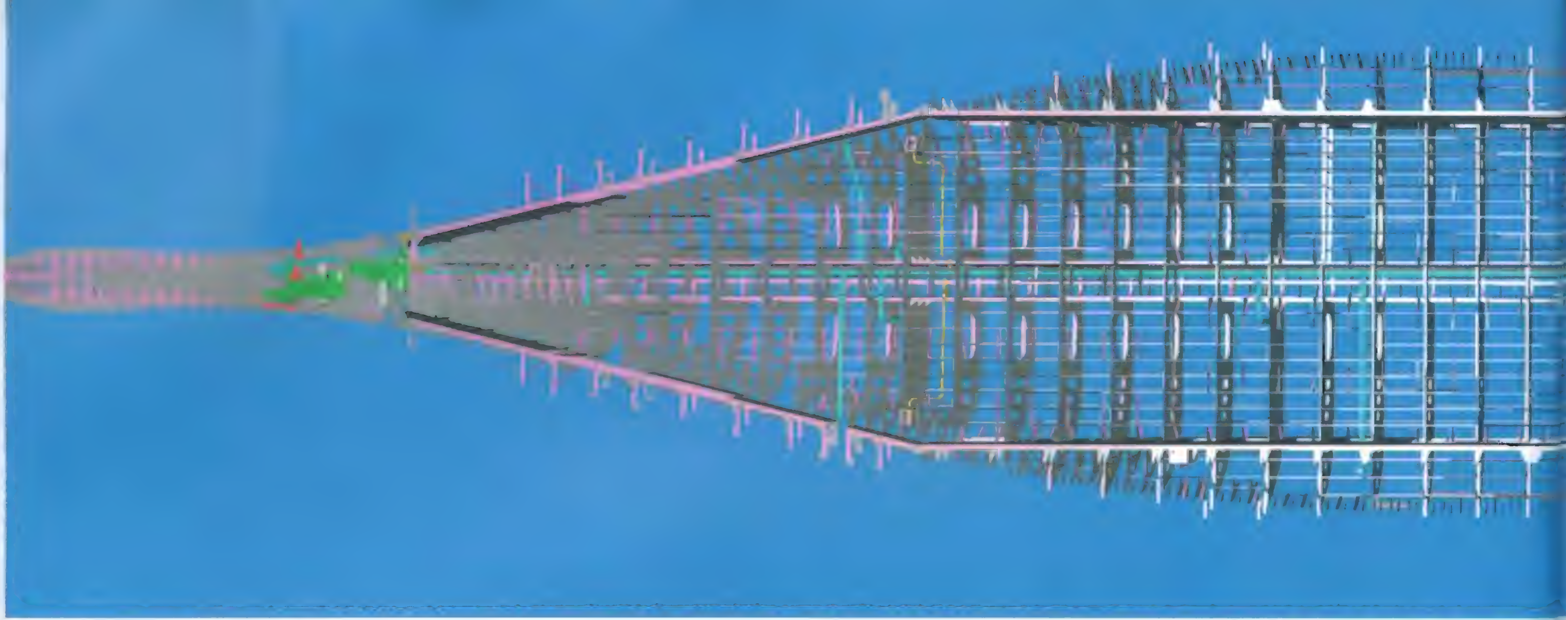
For a good understanding of the spaces and bilge system, see drawing on pages 252-253.

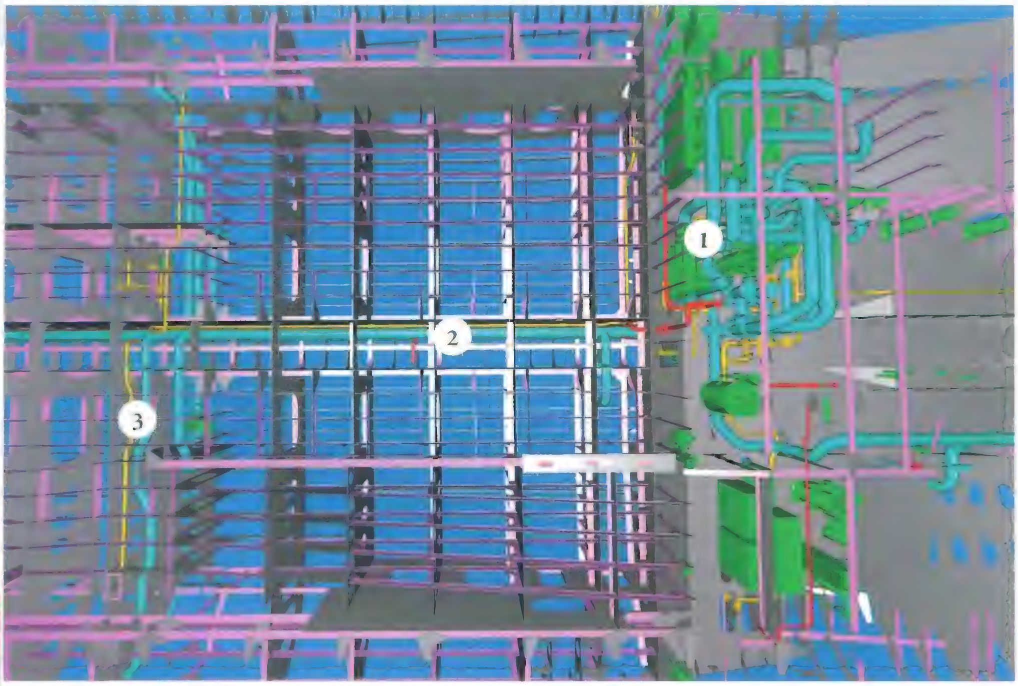
Drawing of the same tug boat on the previous page

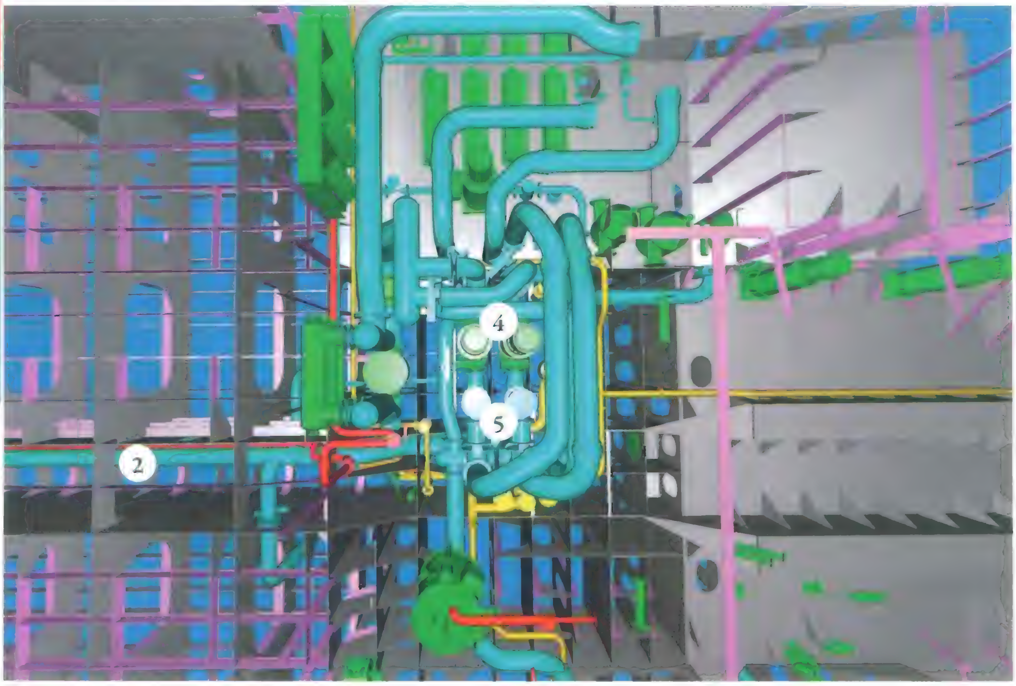




VIEW ON MAIN DECK
REMARKS:
REQUIREMENTS ACCORDING TO TECHNICAL SPECIFICATION, QUALITY ASSURANCE MANUAL
(CONTRACT EXHIBIT IX) AND THE DAMEN HANDBOOKS ARE TO BE OBEYED.
- FOR PIPE INSTRUCTIONS AND DETAILS SEE DRW. : 500000-300-850 UP TO 500000-300-853
500000-300-859
500000-610-851
ALL PIPING SHALL BE ROUTED SO THAT IT IS PROTECTED AGAINST MECHANICAL DAMAGE
ALL PIPING SHALL BE INSTALLED TENSION FREE.
ALL PIPING MUST BE CLEAN BEFORE INSTALLATION.
PIPES MARKED WITH (H) ARE TO BE HOT DIP ZINC COATED ACC. TO ISO 1461 & EN 10240,
BUT PIPES PASSING THROUGH FUEL OIL TANKS MUST BE GALVANISED INTERNALLY
BENDS RADIUS 2 - 3x NOMINAL DIAMETER, UNLESS NOTED OTHERWISE
ELBOWS AND OTHER FITTINGS, TO BE SELECTED FROM THE ANSI - B.16.9 RANGE
(ELBOWS ARE ONLY PERMITTED AFTER WRITTEN CONSENT FROM DAMEN SHIPYARDS)
FOR ARTICLE NUMBERS OF FLANGES SEE HANDBOOK 53
NO FLANGES AND/OR COUPLINGS BEHIND OR ABOVE WALLS OR CEILINGS OR ELECTRIC BOXES.
FOR TRANSPORT PURPOSE: ALL OPEN ENDS OF PIPES MUST BE BLINDED OFF WHERE
POSSIBLE WITH BLIND FLANGES OTHERWISE WITH PLUGS
ALL ECONOSTO VALVES DRILLED ACC. TO DIN 2501-PN10 TO PN40,
PIPE SECTIONS IN ENGINE ROOM TO BE EASILY REMOVABLE AND OF MANAGEABLE LENGTHS.
FOR POSITIONS OF EQUIPMENT SEE FOUNDATION AND ENGINE ROOM ARRANGEMENT DRAWINGS.
PIPING CONNECTED AT EQUIPMENT MUST BE FITTED WITH FLANGES NEARBY TO ENABLE
EASY DISMOUNTING OF EQUIPMENT
FOR MOUNTING INSTRUCTIONS BILGE ALARMS SEE DRW.. 500000-310-851.
- [C] = CLASS CERTIFICATE
- [S] = MED CERTIFICATE.
- [I] = IMO CERTIFICATE.
NOMENCLATURE
D.B. = DIRECT BILGE
E.B. = EMERGENCY BILGE
C.S. = CENTRAL SUCTION
C.D. = CENTRAL DISCHARGE
I.F. = INTERNAL FIRE FIGHTING
L1 = BILGE RPP ROOM
L2 = SUCTION BILGE WATER TANK
L3 = BILGE ENGINE ROOM
L4 = BILGE COFFERDAM FR.40-41
L5 = BILGE CHAIN LOCKERS / FORE PEAK
WATER BALLAST AFT PEAK
S1 = SUCTION BILGE WATER SEPARATOR (OPTIONAL)
= DISCHARGE BILGE WATER SEPARATOR (OPTIONAL)
= DIRECT SUCTION BILGE WATER SEPARATOR (OPTIONAL)
= SPARE (NW 80)
= SUCTION HYDRAULIC COOLING WATER PUMP (NW 50-OPTIONAL)
S6 = SUCTION DISPERSANT (NW40-OPTIONAL
SUCTION SEA WATER COOLED FI-FI ENGINE (NW100-OPTIONAL)
INDICATES PIPES ONLY INSTALLED IF OPTIONAL EQUIPMENT IS FITTED
= OPTIONAL ITEM
NO = NORMALLY OPEN
NC = NORMALLY CLOSED
PERFORMANCE CURVE SIHI AKHK 5101
DAMEN DAMEN SHIPYARDS GORINCHEM
Bilge and internal fire fighting system







Ballast / salt cooling water system seen from three different views.

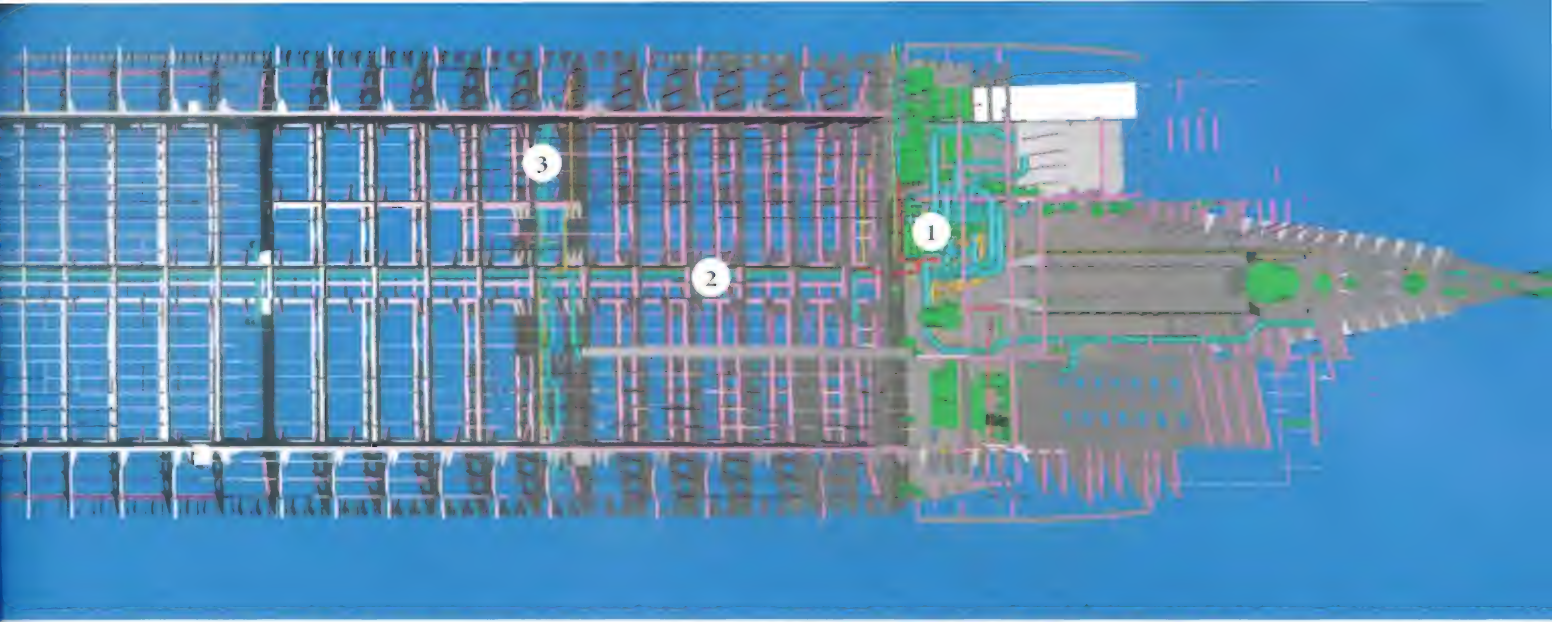
1. Ballast pumps, valves in engine room
2. Main ballast line to tanks
3. Crossover to side tanks
4. Ballast pumps
5. Pump inlet filters

Synthetics for Piping Systems.
More and more pipes on board are made of synthetics, not only for accommodation and sanitary means but also in ballast systems. The main advantage is the corrosion resistance of synthetics. Its light weight is another advantage. The pipes are easier to handle on board as well as on the yard and the reduced weight allows the ship to carry more cargo.

Disadvantages are sensitivity to temperature changes and lower strength compared to steel.

Classification Societies often state that "synthetic pipes may be used when they have no adverse effect on the continuity of vital installations in case of fire or breakdown".

Means for repair of synthetic pipes are compulsory when a vessel makes use of synthetic pipes.



5. Fire-fighting arrangement

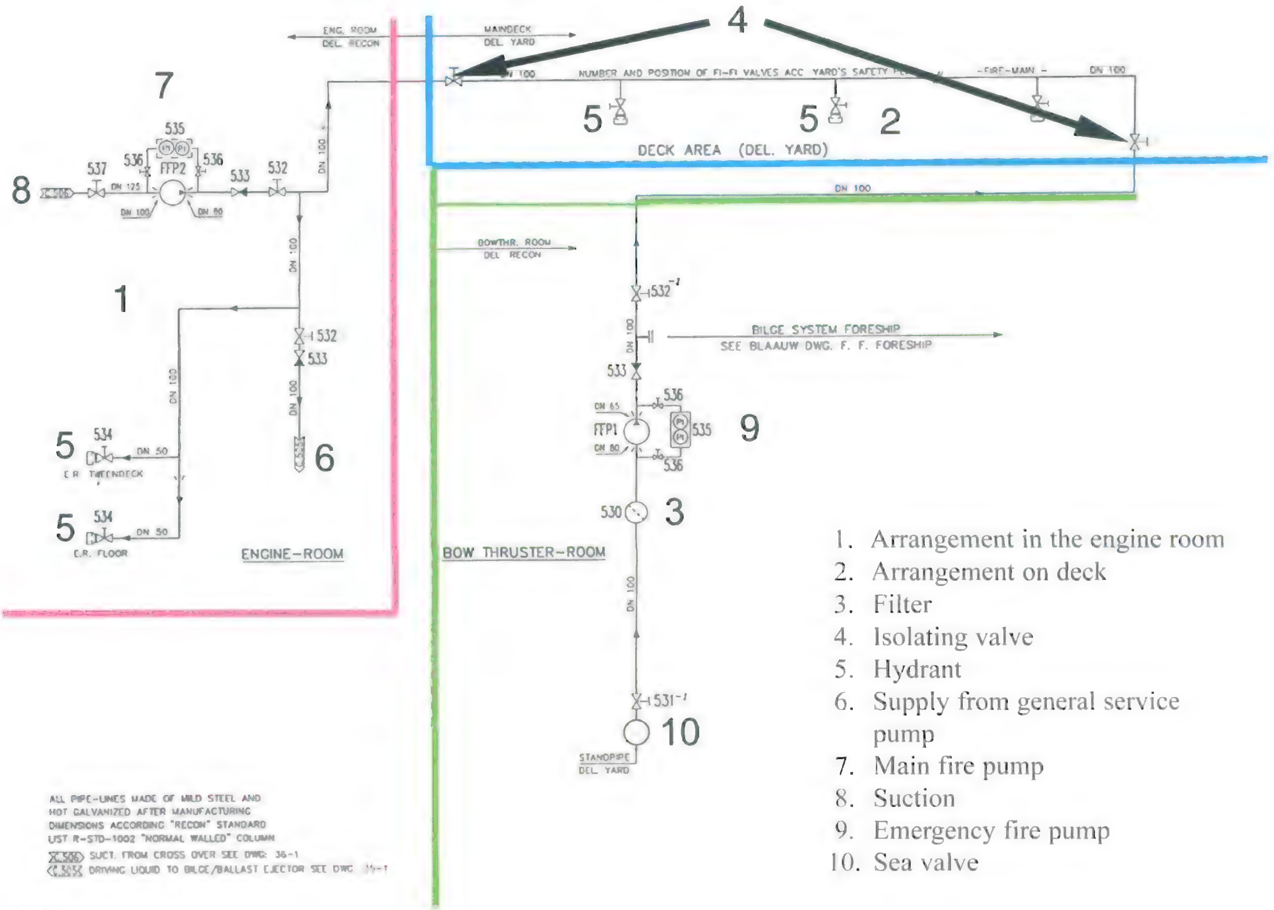
Fire has probably caused greater loss of ships than grounding, collision or bad weather. A good fire-fighting arrangement, conforming to legal requirements, is therefore a necessity.

The fire-fighting arrangement has to transport seawater to the fire hydrants. The system consists of lines, pumps, valves with couplings, hoses, nozzles and spray installations.

A minimum of three fire-fighting pumps is compulsory on all ships. One of these pumps, the emergency fire-pump, must be situated outside the engine room, with a direct connection to the deck fire-line.

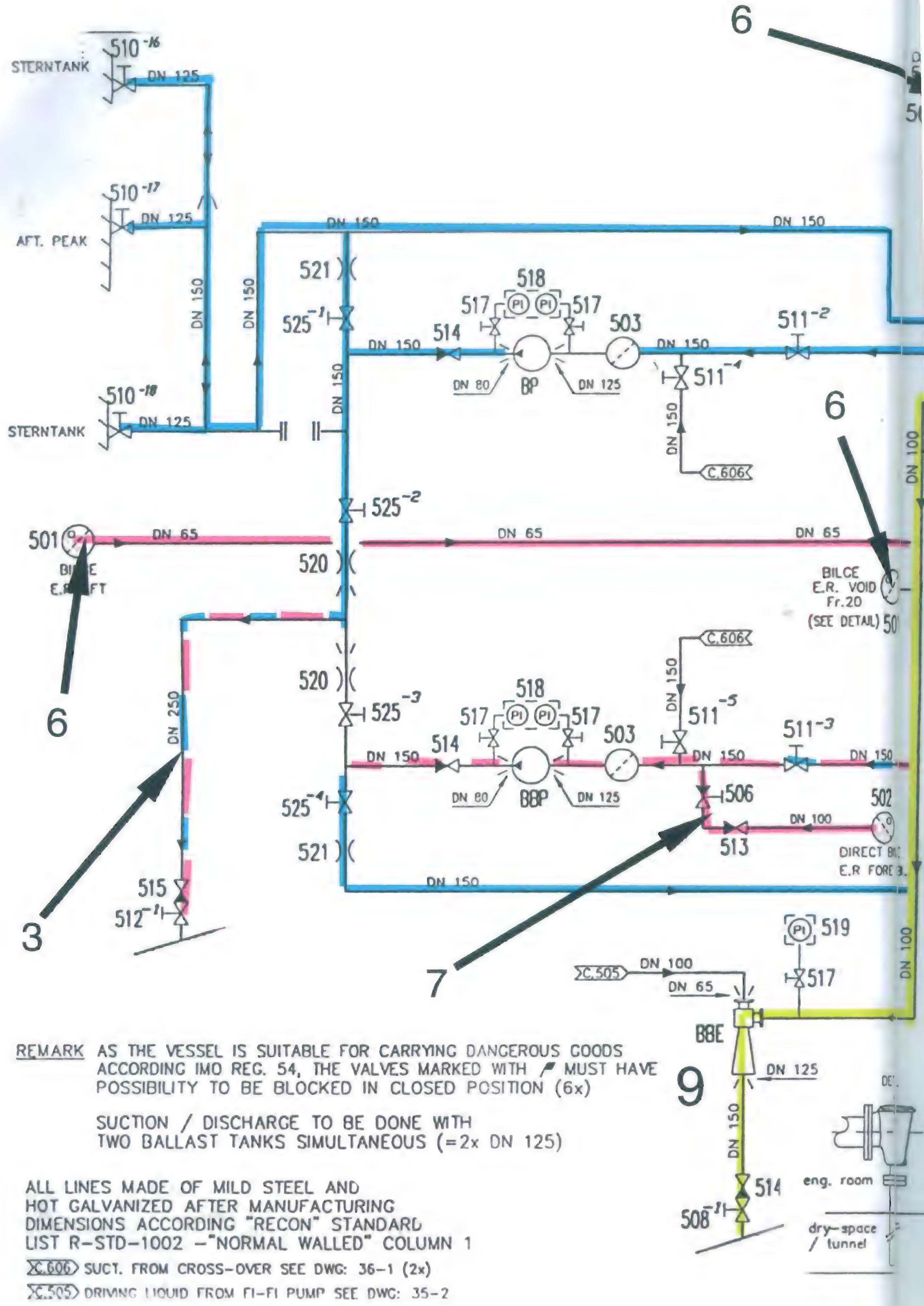
Between the engine room and deck fire-line an insulated valve must be placed, such, that in case of fire in the engine room, the deck lines can be pressurized using the emergency fire pump. The emergency pump may not be driven from the engine room, but independently by a diesel engine or electrically from the emergency switchboard, and thus powered by the emergency generator.

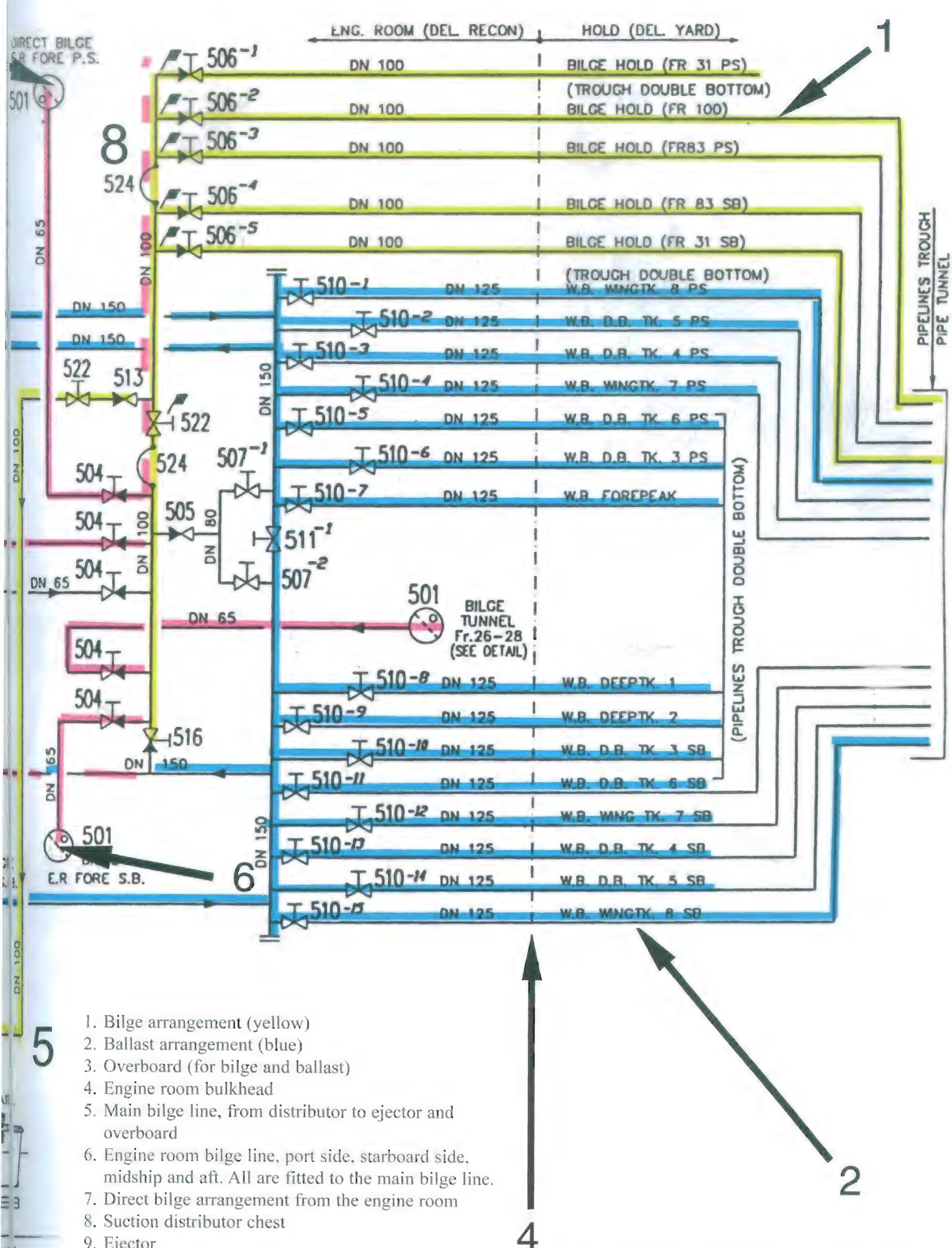
Both main fire pumps must have sufficient capacity and pressure. This pressure should be enough to get at least a pressure of 4 bar at the highest point on the ship (the bridge). There must be enough hydrants to ensure that every location on the vessel can be reached by at least two hoses.



1. Arrangement in the engine room
2. Arrangement on deck
3. Filter
4. Isolating valve
5. Hydrant
6. Supply from general service pump
7. Main fire pump
8. Suction
9. Emergency fire pump
10. Sea valve

Fire-fighting arrangement


6
6
6
3
7
9
STERNTANK
AFT. PEAK
STERNTANK
BILGE E.R. AFT
BILGE E.R. VOID Fr.20 (SEE DETAIL)
DIRECT BI
E.R FORE
BP
BBP
BBE
C.606
C.505
DN 150
DN 125
DN 65
DN 80
DN 100
DN 250
eng. room
dry-space / tunnel
REMARK AS THE VESSEL IS SUITABLE FOR CARRYING DANGEROUS GOODS ACCORDING IMO REG. 54, THE VALVES MARKED WITH ◢ MUST HAVE POSSIBILITY TO BE BLOCKED IN CLOSED POSITION (6x)
SUCTION / DISCHARGE TO BE DONE WITH TWO BALLAST TANKS SIMULTANEOUS (=2x DN 125)
ALL LINES MADE OF MILD STEEL AND HOT GALVANIZED AFTER MANUFACTURING
DIMENSIONS ACCORDING "RECON" STANDARD
LIST R-STD-1002 -"NORMAL WALLED" COLUMN 1
C.606 SUCT. FROM CROSS-OVER SEE DWG: 36-1 (2x)
C.505 DRIVING LIQUID FROM FI-FI PUMP SEE DWG: 35-2

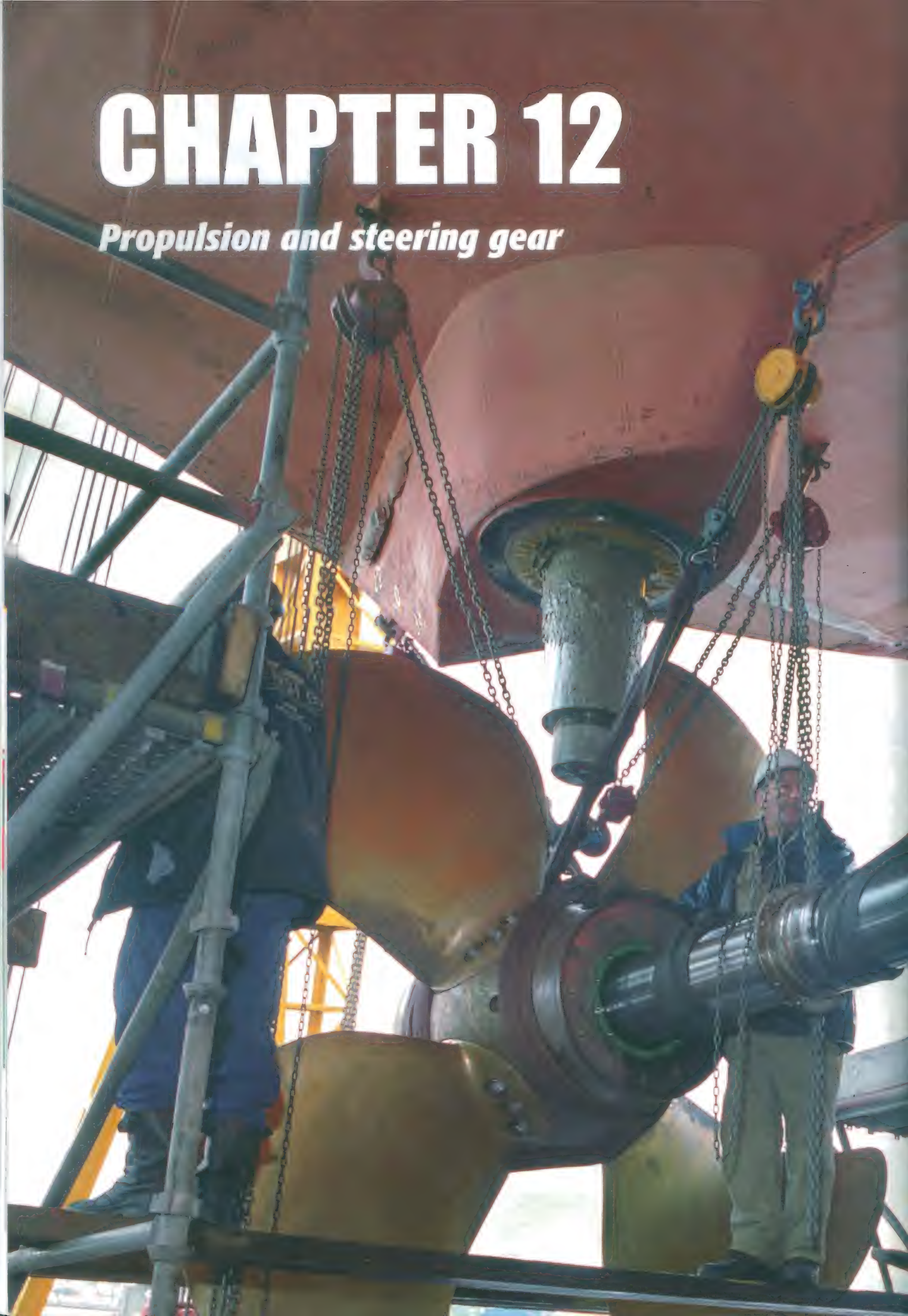


1. Bilge arrangement (yellow)
2. Ballast arrangement (blue)
3. Overboard (for bilge and ballast)
4. Engine room bulkhead
5. Main bilge line, from distributor to ejector and overboard
6. Engine room bilge line, port side, starboard side, midship and aft. All are fitted to the main bilge line.
7. Direct bilge arrangement from the engine room
8. Suction distributor chest
9. Ejector

Bilge and ballast arrangement on a container feeder

CHAPTER 12

Propulsion and steering gear



SHIP KNOWLEDGE

Covering Ship Design, Construction and Operation

QUESTIONS:

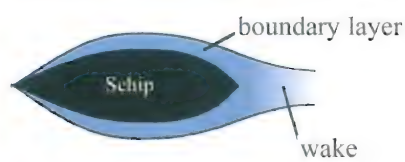
www.dokmar.com

1. Ship resistance

The power required to move a ship through the water depends on the propulsive efficiency and the total resistance of the ship. Resistance is a complex function of **displacement, shape** and **speed**.

The various components of resistance can be divided as follows:

a. Frictional resistance
The friction between the water and the ship's shell is the resistance. The water in the **boundary layer** is accelerated by the ship's speed, dragged by the molecular friction. This boundary layer is thicker, and the resistance higher when the shell is fouled.
Resistance is least directly after delivery of the ship. During the ship's lifetime, the roughness of the hull normally increases, due to paint-layers covering older paint-layers, damage, corrosion, etc. This results in a gradual drop in speed and efficiency.
b. Pressure (form) resistance
The ship's momentum pushes the



The wake of the ship

water aside at the bow and as a result, the pressure of the water increases. This increase in pressure also occurs aft. The pressure will drop where the boundary layer is released.

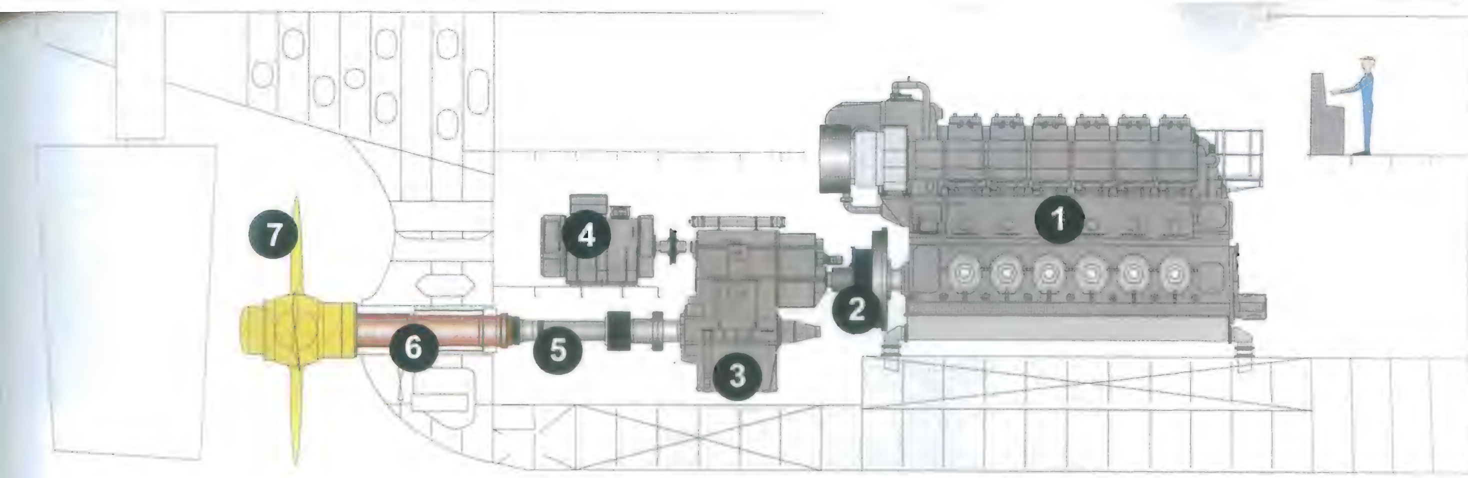
c. Wave resistance
This is a result of wave systems along the hull that originate from the differences in pressure.
On certain ships the use of a **bulb** at the bow can significantly decrease the wave-making resistance. The bulb generates its own wave system, which is designed to interfere negatively with the ship's wave system. The two wave systems then neutralize each other.

d. Added resistance in waves
This type of resistance is caused by the pitching, heaving and rolling of the ship.

e. Air resistance
This depends on the vertical area above the waterline, which varies with the draft. Resistance components as mentioned in d. and e. are variable, depending on wave and wind direction.
N.B. With regard to frictional resistance, the newest hull paint, so-called **non-stick** paint, is silicon-based, which does not allow fouling of the paint and keeps the frictional resistance constant throughout the lifetime of the paint. This paint can also be applied on the propeller, resulting in a smooth hull and propeller, in this way keeping hull efficiency constant. Speed does not drop over time and the fuel consumption of the engine remains constant. It is, however, a very expensive system, only paying off on large, fast ships.

Supplier without a bulb

Container ship with a well-designed bulb



The propulsion system

2. Propulsion

2.1 Propellers

In order for a ship to obtain a certain constant speed, a force needs to be exerted on the ship. The magnitude of this force depends on the ship's resistance applicable to that particular speed. If the ship is moving through the water at a constant speed the force exerted on the ship equals the resistance of the ship. The force that moves the ship can come from an outside source like a towing line or the wind, but generally the force is generated by a power source (engine) on the ship itself. The propulsion system usually consists of an engine or turbine, reduction gearing and if applicable, a propeller shaft and **propeller**.
The efficiency of a propeller holds an important place in the design of the propulsion because its efficiency and the ship's fuel consumption are directly related.

Looking at oil tankers, bulk carriers and container ships it can be clearly seen that the bulb prevents an increase in pressure near the bow. The improved streamline of the ship's underwater body reduces a wave system around the ship. In suppliers and hopper suction dredgers, there is a large wave system present around the ship.

If the rate of flow of water (or air) is higher, then the pressure will be lower compared to the pressure in parts of the water where the rate of flow is lower. Therefore, in waves, water in a trough has a higher speed than water in a wave top. (see chapter 4 'design' and Bernoulli's law).

Efficiency depends on the flow field of the propeller, which depends on:
- the shape of the ship's underwater body
- the power delivered to the propeller
- the number of blades
- rotations per minute
- the maximum possible propeller diameter
- the blade surface area and moothness of the blade
- the ship's speed

In general can be stated that the highest efficiency in propulsion is achieved when the largest possible quantity of water is moved with the smallest possible acceleration. This means that the configuration of a propeller has to be such, that it produces a minimal excess speed in the wake of the vessel. Based on the shape of the after body the ideal propeller accelerates the water that is being dragged in the boundary layer of the ship and produces a minimal and evenly spread excess velocity of the water in the wake behind the ship.

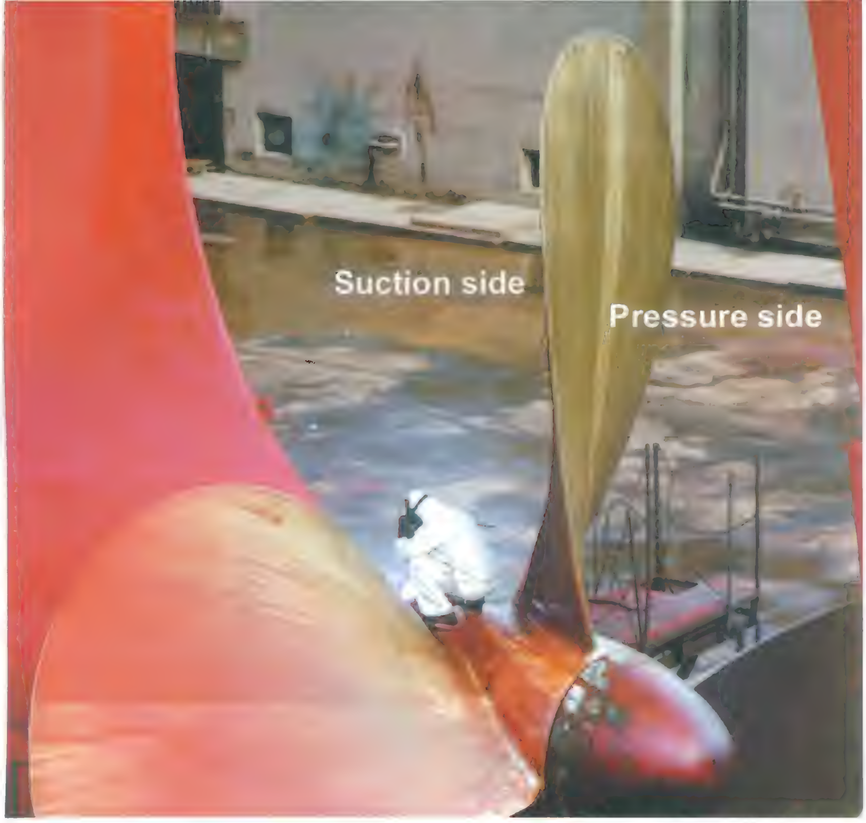
For a given ship speed and power, if the diameter of the propeller increases, the rotations per minute decrease; this generally increases efficiency and thus reduces fuel consumption.
Briefly said, the diameter of the propeller should be **as large as possible** so that a maximum amount of wake, caused by the ship's hull, is used.
The choice of high efficiency with a large-diameter propeller and a low number of revolutions per minute is easily justifiable, but requires a significant investment.
The propeller pitch is the distance in direction parallel to the propeller shaft that a point on the propeller covers in one revolution in a solid substance.

1 Engine
2. Engine shaft and flexible coupling
3. Reduction gear box - reduces the number of revolutions of the engine (e.g.1000 rpm) to an acceptable rotation rate of the propeller (e.g. 200 rpm) The reduction is 5:1.
4. Shaft generator; this supplies the ship with electricity when the engine is running
5. Stern tube with bearing
6. Propeller shaft
7. Propeller

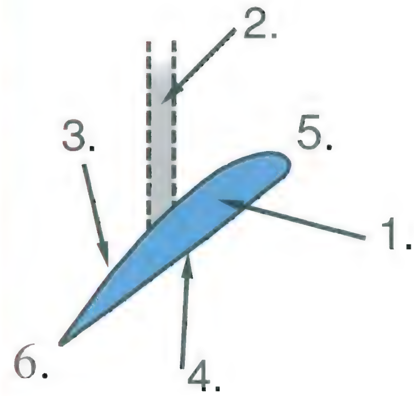
Similar to a point on a corkscrew turning in a cork.
When rotating in a fluid a propeller will have a (small) slip. **Rotations or revolutions per minute are abbreviated as 'rpm'.**

RPM and the number of blades influence vibrations on board and the resonance frequency of the ship. Most small single screw ships use a 4-blade propeller, while 5-blade propellers are more common on bigger ships where more power (20,000 kW) is necessary.
However, today, more and more ships use the 5-blade version, even when less power is needed, to reduce vibration. 3-blade propellers are used on twin screw vessels and on ships with a high number of revolutions per minute and low power (700 rpm, 600 kW).

Usually, the number of the blades coincide with th number of the motor's cylinders. The reason is that specific reverberation phenomena can occur in the motor propeller shaft if the number of cylinders don't correspond with the number of the blades.



Fixed right-handed propeller on a tanker (deadweight 30,000 tons). Propeller being polished to reduce roughness, for less rotation friction and fuel consumption.



A drawing of the upper fixed propeller blade of a right-handed propeller seen from above

1. Cross-section of propeller blade
2. Propeller shaft
3. Suction side
4. Pressure side
5. Leading edge
6. Trailing edge

Different types of blades attached to a hub. This combination can never be used for actual propulsion

2.1.1 The shape of the blades

Every propeller is designed individually as a selected compromise between the level of efficiency and cavitation related side effects such as excitation of vibration or danger of erosion damage due to cavitation.

The remarks for each shape of blade apply to both fixed and controllable pitch propellers.

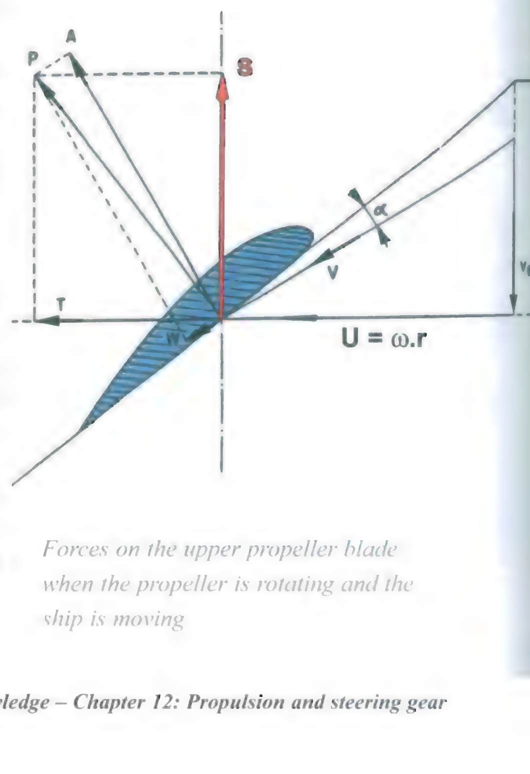
Blade 1- The standard blade. For certain reasons other shapes are chosen, but on normal ships still often used
Blade 2- highly skewed, reducing vibration and noise
Blade 3- Higher area (Fa/F), low pressure, thus reducing cavitation
Blade 4- Typical blade for use in nozzles, large area
Blade 5- Also for use in nozzles, but producing less vibration and noise

2.1.2 Pressure and suction sides of the propeller

The approach velocity of the water is a result of the ship's movement through the water. If the ship has zero speed, this Ve = 0. Approach velocity can be calculated by subtracting the wake velocity from the ship's speed. The speed of rotation of the propeller and the approach velocity result in the speed (V).
This V hits the propeller blade at a certain angle:
$\alpha = 9^o\text{-}10^o$ at service speed

The speed of the incoming water creates underpressure on the forward side of the blade (suction side) and pressure on the aft side of the blade (pressure side). The propeller blade acts similarly to a wing profile. Propellers are usually viewed from aft, therefore the pressure side is also called 'the face' and the suction side 'the back'.

Ve = approach velocity – ship's speed - wake speed
U = speed of rotation of the propeller
ω*r = angular velocity * radius
V = resulting speed
A = lift
W = drag
P = resulting force
S = propulsion force (thrust)
T = shaft moment



Forces on the upper propeller blade when the propeller is rotating and the ship is moving

Cavitation damage on a propeller blade on a CPP due to missing plug.

Cavitation damage on a rudder blade

2.1.3 Cavitation

As described above, the propeller pressure of a rotating propeller is not just the result of the water-pressure on the pressure side, but also of the underpressure on the other side of the propeller. Propellers that rotate rapidly can create underpressure that is so low that water vapor bubbles form on the suction side of the propeller. These gas bubbles **implode** again when the pressure rises, continuously on the same spot. When this is located on the blade surface, it causes damage to the suction side of the blade. This is called cavitation. Severe cavitation results in:

- increase of blade roughness
- a reduction in propulsion force wear of the blades
- vibrations that bend the blades
- noise in the ship
- high costs

A properly working propeller often shows light cavitation at the blade edges which is not harmful.

2.1.4 The influence of the propeller's turning direction on the ship's maneuvring.

Propellers can be divided into right-handed and left-handed propellers. Ships with a fixed-pitch propeller usually have a right-handed version.
A right-handed propeller can be recognized by standing aft of the propeller, while looking at the face and holding on to the top blade with both hands.

If the right-hand side of the blade is furthest away, it is a right-handed propeller. If the ship is going ahead, a right-handed propeller is rotates clockwise.
When a propeller is rotates, the ship has the tendency to turn to a particular side, even if the rudder is in the mid ships position and there are no additional forces acting on the ship. This effect is called the propeller effect or **wheel effect** (see section on maneuvring).

Propellers with adjustable blades (controllable-pitch propellers, abbreviated CPP) are often left-handed. When the propeller is in the astern mode, turning anti-clockwise, the effect of the propeller is the same as in a right-handed propeller going astern, also turning anti-clockwise. When moving forward, they have the same effect as a left-handed propeller. This is done in order not to confuse pilots.
When going astern, the efficiency of the propeller can drop below 50% of efficiency when moving forward, depending on the type of blade and propeller.

2.1.5 Alternative propeller designs

Apart from the blade form and number of blades, many alternative designs have been tried and tested.
Propellers with tip plates were invented around 1850, but have only recently been rediscovered. **Tip plates** are attached to the blade tips.

The plates prevent the water from flowing too fast from the pressure areas to the suction areas of the propeller, resulting in vortices. They also increase efficiency by reducing energy loss. The improved hydrodynamics of water flow caused by tip plate propellers also contribute to the reduction of vibrations and noise of the propeller.
Another development is the **contra rotating** propeller. This system consists of two propellers placed one behind the other, which are driven by means of concentric shafts (inner and outer shafts) with opposite directions of rotation. Both the number of blades and the diameters differ.

Propeller with tip plates

Model test of a contra rotating propeller

Propeller	Turning direction	Sailing direction	Direct propeller effect		Indirect propeller effect	
			Aft	Fore	Aft	Fore
right-handed	right	ahead	starboard	port		
right-handed	left	astern	port	starboard	port	starboard
left-handed	right	astern	starboard	port	starboard	port
left-handed	left	ahead	port	starboard		

Wheel effect of propellers

The principle of this system is that normally water is brought in rotation by the propeller, which results into a loss of energy. Adding a second propeller rotating in the opposite direction reduces the loss of energy. The combined propellers can reduce fuel consumption by 15%.

2.2 Fixed pitch propellers

The propeller blades of a fixed pitch propeller have a fixed position. As a consequence the direction of rotation of the propeller has to change if the ship stops or must goes astern. This is realized with a reversing clutch or a reversible engine. A reversing clutch, and therefore also the fixed pitch propeller, is economical in ships up to 1250 kW.

The diameter of fixed pitch propellers varies between 25 cm and 12 meters. The choice of a fixed or a controllable-pitch propeller (CPP) depends on, among other things, the need for a shaft generator and the need for easy maneuvring qualities.

Fixed right-handed propeller of a container vessel (GT 80942) with a reversible engine. The propeller weighs 95 tons, has 6 blades and a diameter of 8,95m

Installation of a fixed right-handed propeller with shaft

Advantages of a fixed propeller over a controllable pitch propeller are:

- they are less vulnerable to damage
- the propeller does not revolve when berthing, so it imposes less danger to mooring boats and there is less risk of ropes getting entangled in the propeller

Disadvantage of the fixed propeller over a CPP are:

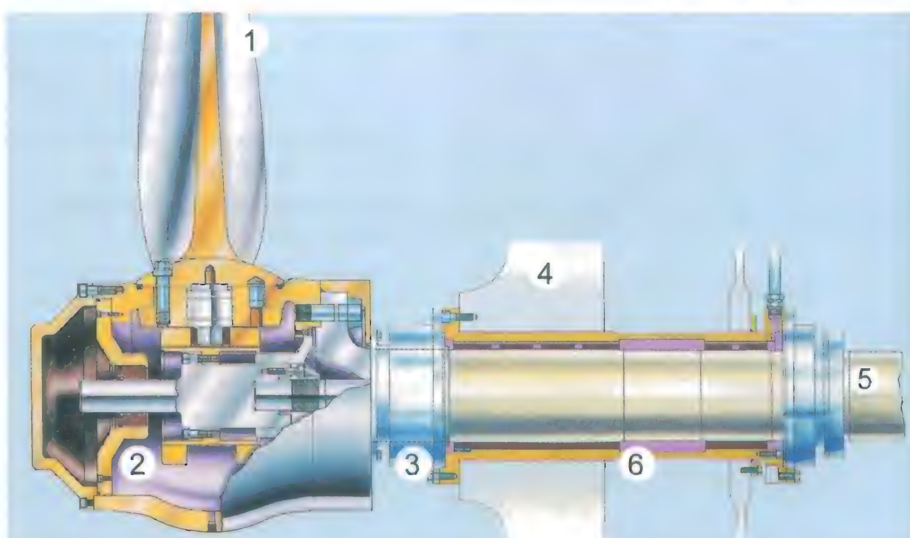
- in adverse weather, the propeller may have too many RPMs, which can hamper propulsion
- fixed propellers also have a limited range of RPMs for maneuvring and power.

2.3 Controllable pitch propellers (adjustable pitch propellers)

The blades of this type of propeller can be turned around the blade-axis, thereby changing the propeller pitch. These propellers are internally complicated. The mechanism that adjusts the propeller pitch is located in the propeller boss. It is activated from the engine room and remotely controlled from the bridge by a hydraulic cylinder. The most striking feature of the controllable pitch propeller is that it only rotates in one direction, making the reversing clutch or reversible engine unnecessary. Unlike the fixed pitch propeller, the controllable pitch propeller is an integrated part of the propulsion system. This makes it possible for power and necessary propulsive forces to be controlled by simply changing the positions of the blades.

The figure on the following page shows cross-sections of a propeller blade and the forces that act on that part of a rotating propeller blade.

On the left are the cross-sections and forces when the ship is going ahead.



All the vectors point backwards while the ship is going forward.

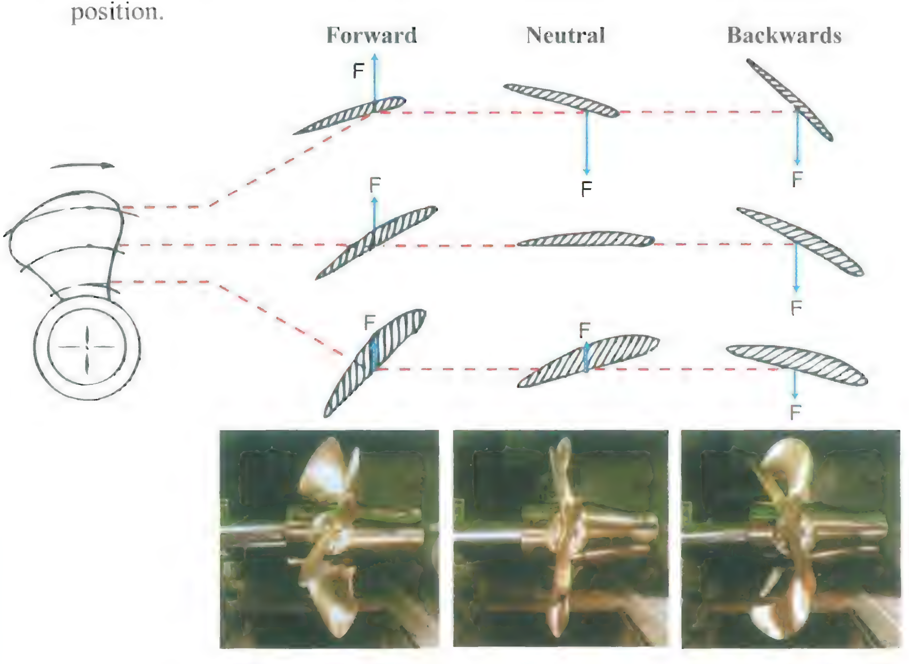
Now the blades are rotated towards the zero position. This means that the propulsive forces above and below are equal in magnitude, but opposite in direction. The net propulsive force is zero, but the propeller still absorbs a large amount of energy that is converted to turbulence of the wake. To go astern, the blades are rotated even further, resulting in a forward propulsive force.

Safety precautions

1. The position of the blades can be changed manually without loss of propulsive force.
2. If the hydraulic system fails, the blades can be locked in the ahead position.

Advantages of a controllable pitch propeller:

- It can propel the ship at all speeds, even at very low speed without stopping the engine
- It can change quickly from ahead to astern and vice versa
- Improved efficiency on ships such as fishing craft and tugs with changing power demands
- It can easily be combined with a shaft generator (see below)
- It can stop a ship with maximum power
- In case of propeller damage, changing a blade is sometimes possible afloat, depending on the ship's type and trim possibilities



Drawings of a single propeller blade and its cross-sections. The pictures show the controllable pitch propeller; the upper blade is the blade in the drawings.

The shaft generator can supply the electrical power on a ship as long as the main engine keeps running. With controllable pitch propellers the generator frequency can be kept constant because the rpm of the engine remain constant. The engine drives the shaft generator via the reduction gear box.

When a shaft generator is fitted which can also work as an electric motor, with a power supply from the auxiliary diesel generators, the electric motor can produce propulsion power, i.e. in case of major main engine problems for emergency propulsion.

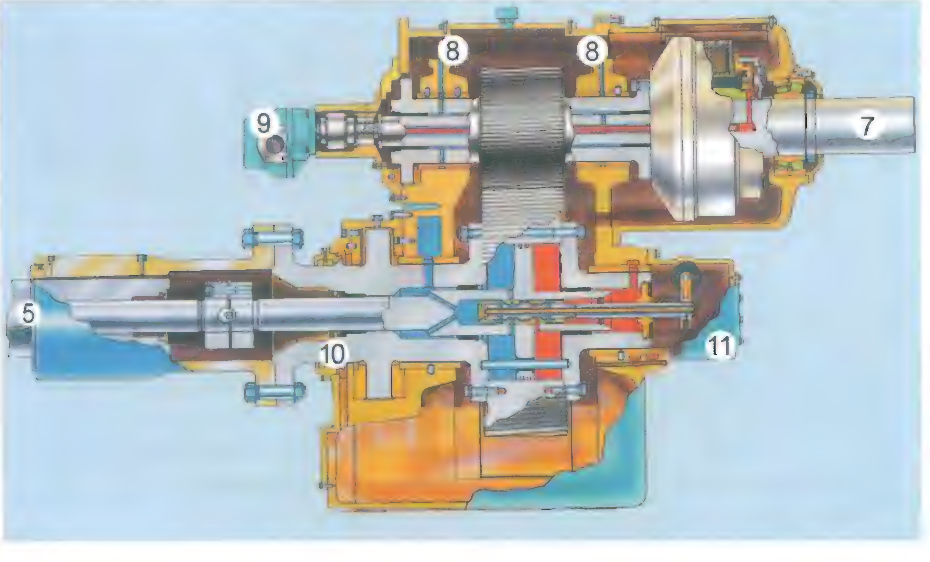
Class does not require this system and/or the maximum speed it can obtain. The system is sometimes used on small ships.

A shaft generator can produce electric power during maneuvring also, which is economically advantageous.

Disadvantages:

- CPP systems are vulnerable due to the hydraulic components and many sealing rings. A damaged sealing ring can result in oil pollution.
- price
- inefficiency

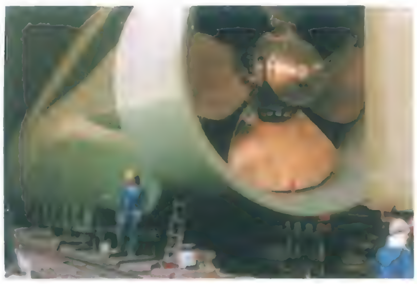
1. Propeller blade (tip speed 31,4 m/s)
2. Boss or hub
3. Watertight / oil tight seal
4. Stern frame
5. Propeller shaft, 240 rpm
6. Stern tube
7. Intermediate shaft (to engine shaft)
8. Reduction gear box (1:2.5)
9. Mechanically driven lubricating oil pump
10. Collar shaft (thrust)
11. Actuating motor, coupled to a mechanism of bars that serves the blades.



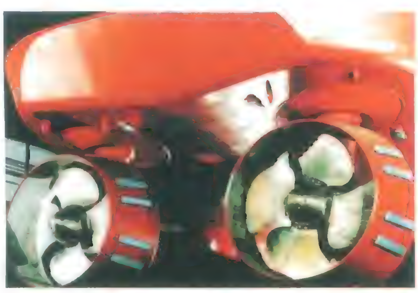
Drawing of a controllable pitch propeller with propeller shaft. The pitch adjustment of the blades is done via oil pressure through the hollow shaft. The figures apply to a propeller with a diameter of 2.5 meters.

2.4 Nozzles

The purpose of a nozzle is to increase the propulsive force. This increase results from the fact that the propeller forces water to flow through the nozzle. This water flow has a higher velocity in the nozzle than the water outside and the resulting pressure difference then creates the additional propulsive force. The efficiency of the nozzle is at a maximum when the water can pass unobstructed. This is why the top of the nozzle should always be as free as possible in relation to the aft body.
Not only does a nozzle increase the propulsive force, it also reduces noise and vibration levels.


Controllable pitch propeller in a fixed nozzle


Fixed propeller in a nozzle rudder

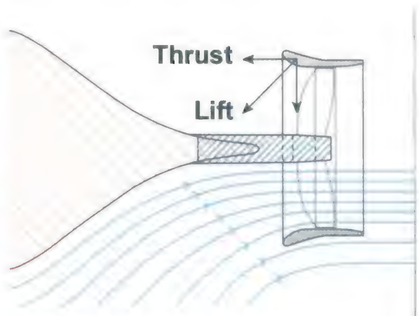

Two rudder propellers in a nozzle, with 360° rotation.

Furthermore, the incoming water flow is more homogeneous in a nozzle, minimising local pressure differences responsible for cavitation and vibrations.
The combination of a propeller in a nozzle is often called a ducted propeller. In principle, the nozzle can be used on every type of vessel except on very fast ships like high-speed ferries where they have no increasing effect on the propulsive force. If the frictional resistance (caused by the nozzle) becomes larger than the increase in propulsive force, the nozzle is not effective. Nozzles are often used on inland vessels, hopper suction dredgers, tugs, fishing vessels and suppliers. The advantages and disadvantages of fixed or controllable pitch propellers are the same for propellers with a nozzle and propellers without one. For shallow draft ships the same thrust can be delivered with a smaller system diameter.

Nozzles are fitted as:

- fixed versions
  nozzle rudder propellers: the whole system including propeller can rotate around a vertical axis, 360°
- nozzle rudders: Propeller fixed, nozzle can turn as a rudder (35° à 40° max.).

One particular type of fixed nozzle is the wing-or Schneekluth nozzle. Only applicable to ships with a full body that lack wake velocity in the upper half of the propeller circle. This nozzle is fitted forward of the upper part of the propeller against the stern frame in two halves, with different axis angles in relation to baseline and centerline. The nozzle is anti-rotating and brings water to the top halve of the propeller circle, where the velocity of the incoming water in a full ship is low. In spite of its modest dimensions, this still increases the propulsive force if the speed exceeds 12-18 knots.



The lift force, created by the underpressure on the outside of the nozzle

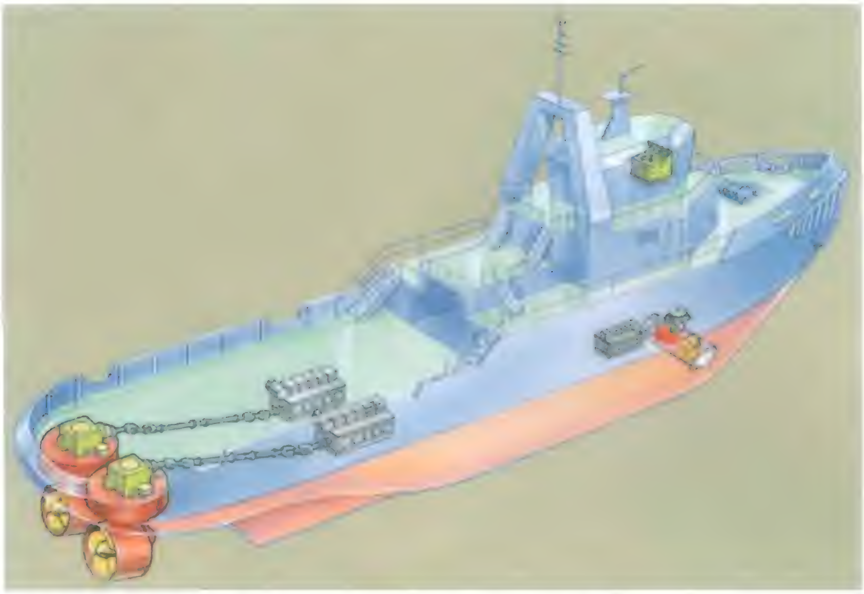
2.5 Rudder propellers

The main characteristic of rudder propellers is their ability to rotate like a rudder, if unobstructed, the full 360°. Rudder propellers are also called 'azimuthing thrusters' or 'Z-drives'. To achieve this freedom of rotation, a right-angle underwater gear box is driven by a vertical power shaft. This vertical shaft is centered in the rudder stock. A gear driven by a pinion is attached to the top of the rudder stock. This makes the unlimited rotation possible.

Nowadays, rudder propellers can have a power up to 7500 kW. There are several versions of rudder propellers, namely:

1. A fixed unit assembled in an assembly box - it can be equipped with a depth adjustment system. When the ship is empty, the propeller can be lowered in order to get sufficient propulsive force efficiently without the need for ballast.
2. Deck units - the diesel-drive units are placed on deck; the rudder propeller is attached to the back of the drive unit. These types can also have a depth adjustment system.
3. A retractable unit. It can be withdrawn entirely into the ship and is only lowered when the ship is at sea. When in top position, the propellers can then be part of a tunnel thruster and are then called 'retractable thrusters'. Not used for main propulsion.
4. Bow thrusters or stern thrusters. Also called tunnel thrusters. They are based on a transverse propeller and a right-angle underwater gear box. These are used exclusively to position the ship with a starboard or port side thrust. When the ship's speed is above 6 knots, their influence is negligible.

Types 1 and 2 function as main propulsion units, while type 3 is an auxiliary propulsion unit.

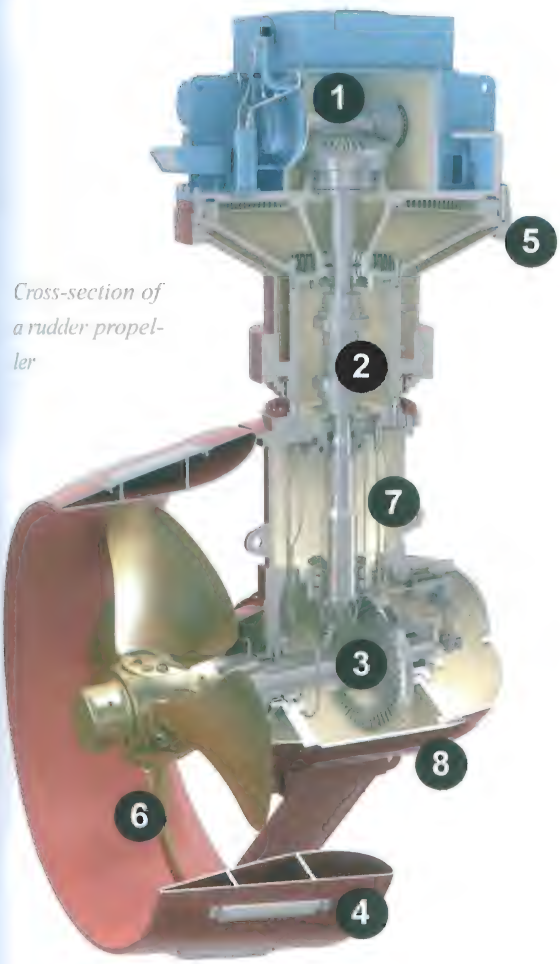


Tug boat equipped with two azimuthing thrusters and a bow thruster

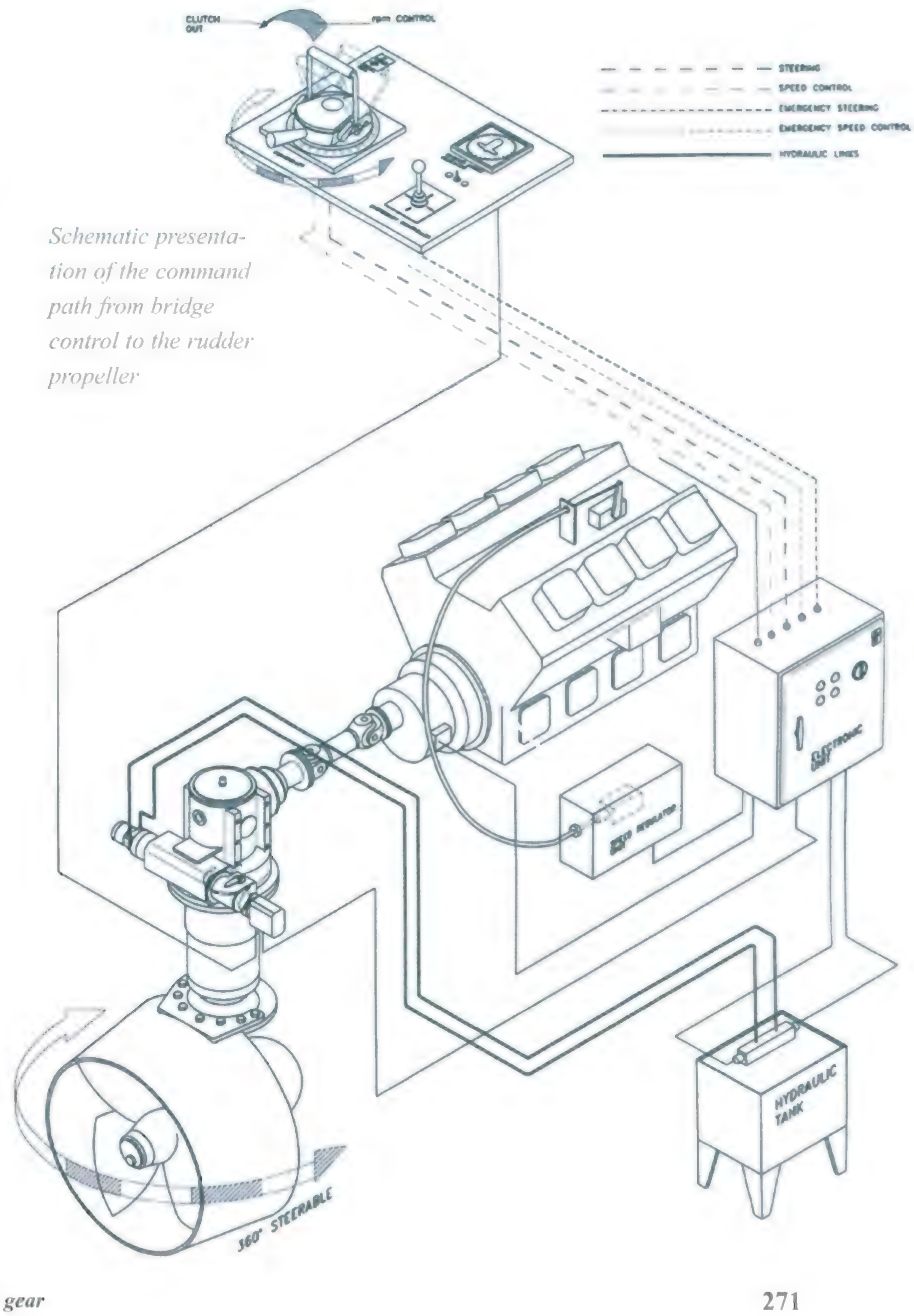
Type 4 is for low-speed maneuvring. The most important advantage of a rudder propeller is its ability to give optimal thrust in each rudder position.

With exception of the tunnel thruster, all rudder propellers can steer the ship 360°, thereby giving the ship excellent maneuvrability.

Today, modern electronic equipment for satellite navigation can be employed to couple the rudder propellers to the dynamic positioning system (DP-system). This can keep a ship in a pre-determined position irrespective of the influences of currents, waves and wind. Retractable thrusters are often used for this purpose. When the ship has arrived at its position, the azimuth thrusters are lowered and the ship switches to DP.



Cross-section of a rudder propeller



Schematic presentation of the command path from bridge control to the rudder propeller

1. Driveshaft from engine, with gears
2. Vertical driveshaft
3. Propellor shaft with gears
4. Kort Nozzle
5. Rotation point in ship's construction
6. Controllable Pitch Propeller
7. Hydraulic lines to CPP
8. Oil-Filled gearbox

Other advantages of the rudder propeller are the very compact engine room (because there is no need for a long propeller shaft); this results in lower installation costs as compared to a conventional propeller.

Rudder propeller installations are often used on passenger ships, cable ships, floating cranes, suppliers, dredgers, barges etc.

The joy stick on the control panel is a so-called 'one-man operated joy stick system', which controls the entire propulsion system and the rudders.

Aerial photograph of a supplier shows the optimal maneuvring capabilities of a rudder propeller in combination with a bow thruster

Good maneuvrability of electrical rudder propellers The turning circle of a ship with electrical rudder propellers as compared to the sister ship that uses separate rudders and propellers

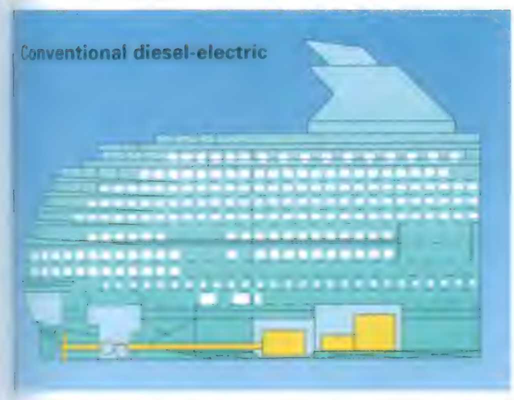
Control panel

1. Joystick
2. Control automatic pilot
3. Read-out of daughter compass

Aerial photograph of a ferry showing thruster wash

Drive via rudder propeller

Direct-drive engine to propeller



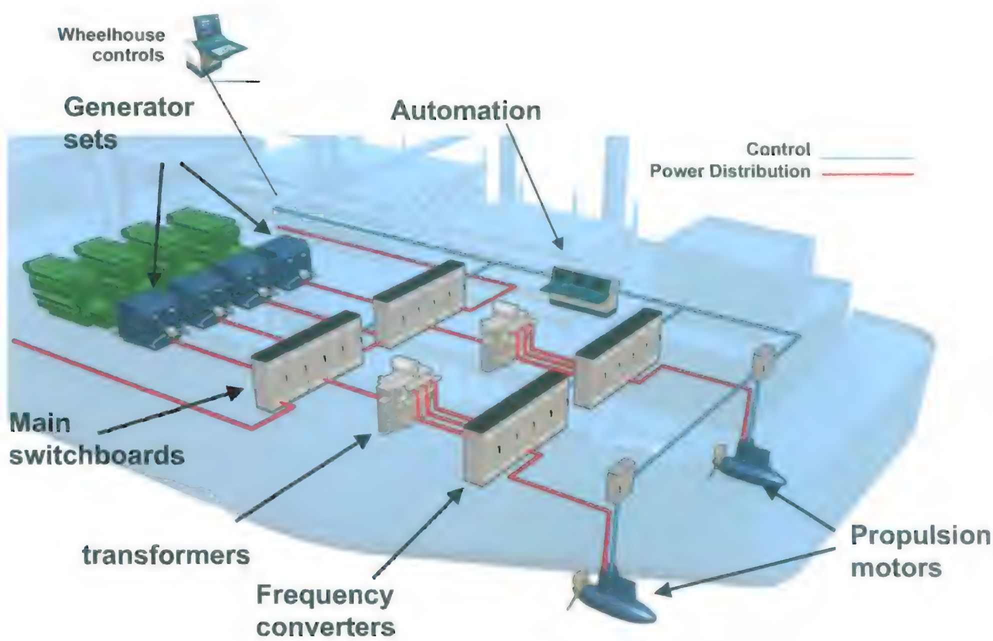
Diesel-electric drive

2.6 Electrical rudder propeller

(Brand names: Azipod, Dolphin, Mermaid, SSP)

The difference between the rudder propeller of paragraph 1.5 and the electric rudder propeller or podded propulsor is that the latter has its propulsion engine located outside the ship hull. The electrical engine with adjustable RPMs is placed in a pod attached to the bottom of the ship. Every **pod** has a propeller attached to it, driven by the electric motor inside the pod. There are two main types: a fixed pod with a rudder or a 360^0 rotating pod without a rudder. Both types can either push or pull. The propeller is then located at the back or front of the pod, respectively.
The electric rudder propeller does not require gear boxes, clutches, propeller shafts and rudders.

A cruise ship with 2 electrical rudder propellers that can rotate 360°.

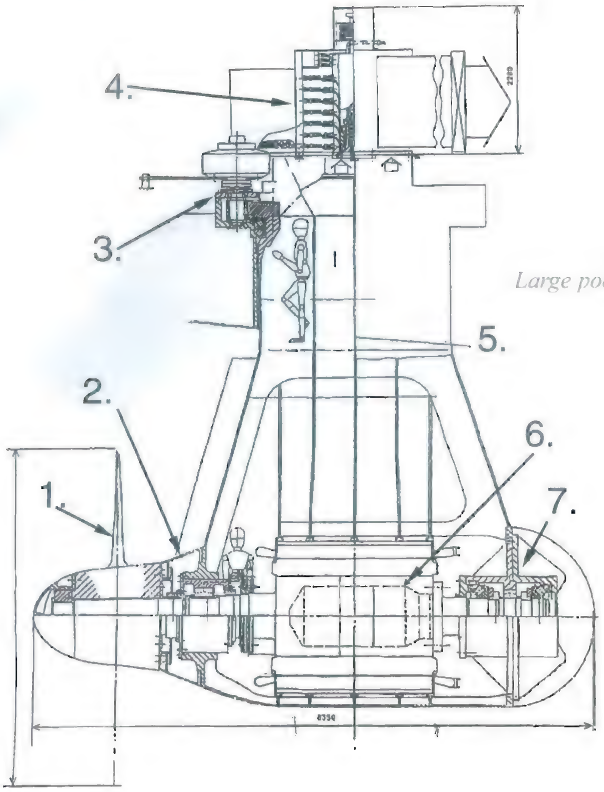


Arrangement of a diesel-electric propulsionsystem using electrical azipods, with the power supply by diesel generators.

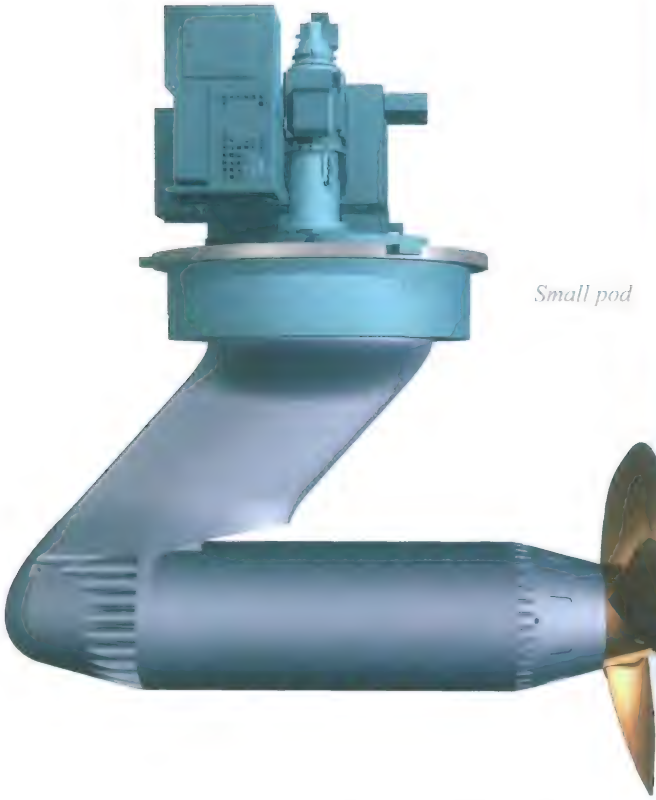
The diesel generators can be placed anywhere on the ship, as long as there is space available, unlike the ships with a mechanical drive where the engines are connected to the propeller by a long shaft and other parts.

This makes this propulsion system a compact system that simplifies the design and construction of the ship as compared to conventional propulsion systems. Although the system was originally developed for icebreakers, it is now in use on suppliers, cruise ships, tankers, ferries and ships with a DP-system.

Advantages are:
1. It is possible to separate the power source and the propulsion system
2. It can combine the power supply of the auxiliaries and the propulsion system
3. Few vibrations and little noise
4. Excellent maneuvring capabilities
5. Lower fuel-costs



Large pod


Small pod

1. Propeller
2. Bearing and shaft labyrinth (seal)
3. Hydraulic steering unit with toothed rim
4. Collector rings for the transmission of data and power
5. Ship's bottom
6. Electro-motor
7. Bearing (radial and thrust)

2.7 Propeller shafting

The stern tube contains the bearings in which the propeller shaft is rotates. Usually, there are two bearings, the one most aft being the longer. Close to this aft bearing is the sealing system that keeps the seawater out of the stern tube and the oil inside.

The front side of the stern tube is welded to the aft peak bulkhead, the aft part to the stern or propeller post. After welding, the tube ends are machined in situ, in accordance with the alignment of the shafting in relation to the main engine.
The sealing system must be able to withstand extreme conditions such as:
- circumferential speeds up to 5 m/s
- water pressure up to 3 bar
- axial and radial propeller shaft displacements of approximately 1 millimeter
- the ship's vibration
- 7000 hours of rotation-time per year, over 5 years

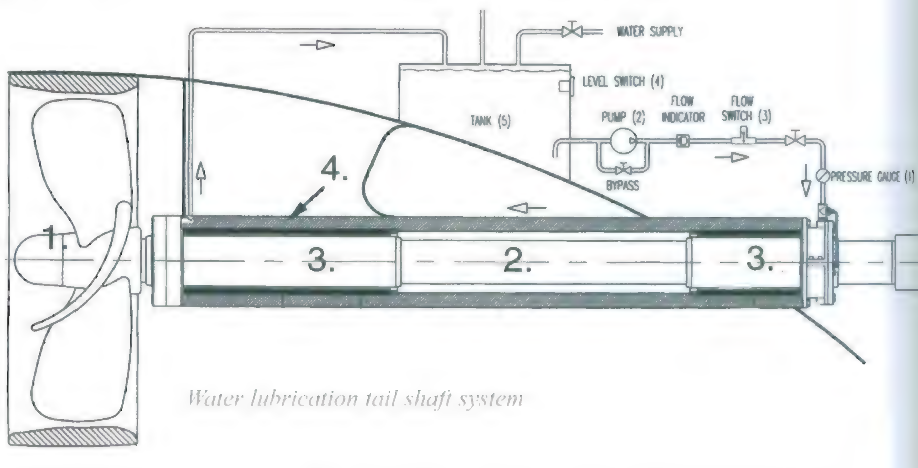
Shaft alignment can be complex. In small ships it is usually a straight line, but in large ships with heavy shafting systems, the alignment is calculated and bored in accordance with the flexible line of the installed and coupled shafting.

The lubricating agent between the propeller shaft and the shafting can be:
a. water
b. oil

a. Water as a lubricant
When water is the lubricant for the propeller shaft, the bearings are made of rubber or synthetics. Water lubrication can be achieved with both open and closed systems. In the open system, there must be flow, usually generated by a pump, through the stern bush from forward to aft, thus preventing seawater from entering the ship. In the closed system, the water is pumped round the shaft, from fore to aft. This means that the water inside the stern tube always has a slight overpressure as compared to the outside seawater. The Navy prefers water lubrication because seals, in use with oil lubrication are vulnerable to pressure shocks from, for instance, depth charges. The seals are then blown inwards, and the sealing properties are lost.
In some countries water lubrication is compulsory for local shipping to protect the environment.

Bearing: that part of a machine in which a rotating part rests

1. Propeller
2. Tail shaft
3. Shaft bearing (Rubber, lignum-vitae, tufnol)
4. Stern tube



Water lubrication tail shaft system

1. Stern
2. Rudder
3. Propeller cap
4. Propeller
5. Skeg
6. Aft stern tube seals
7. Shafting
8. Forward stern tube seals
9. Intermediate shaft bearings
10. Propeller shaft

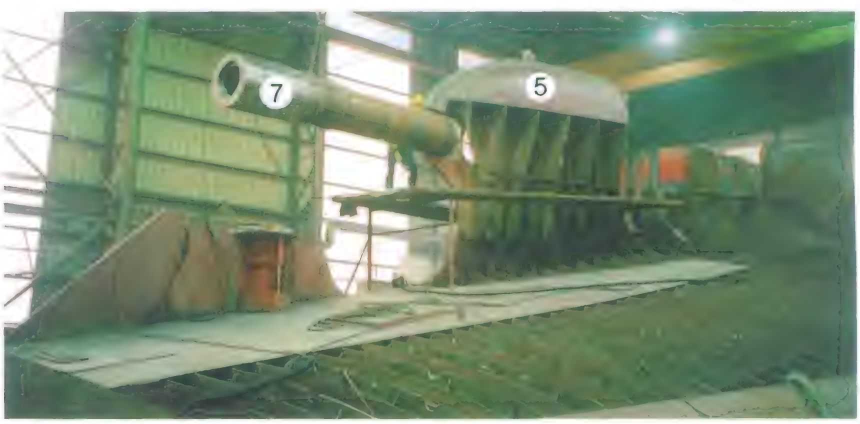
Stern with a controllable pitch propeller.

b. Oil Lubricated Shafting

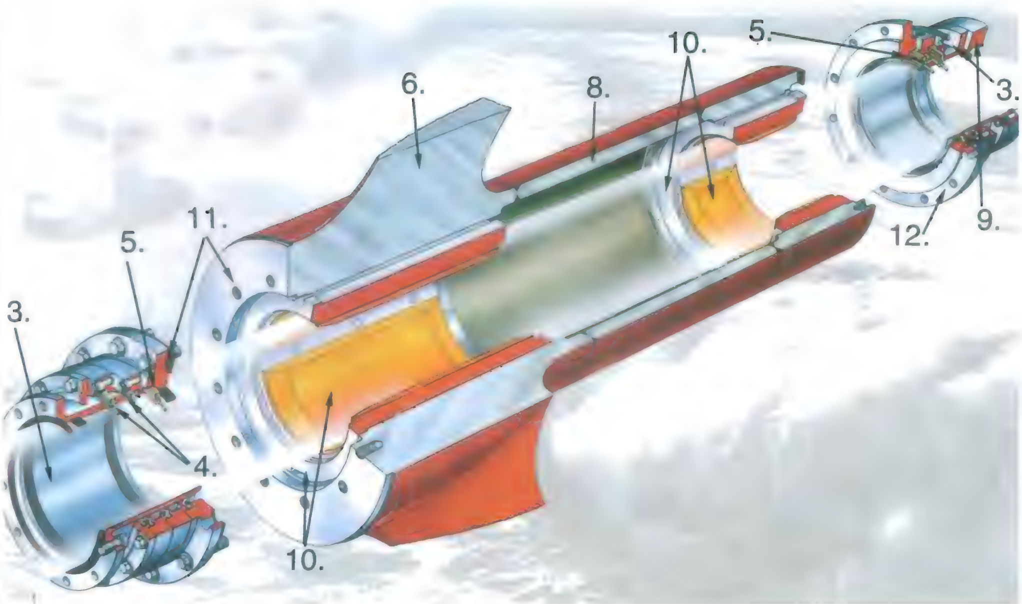
Approximately 70% of all ships use oil as a lubricant for the propeller shaft. In that case, the bearing is usually made of white metal, and sometimes of synthetic material. White metal is superior.

The disadvantage of synthetic materials is that they transmit the frictional heat between bearing and shaft poorly. The oil-filled tube, with the shaft in center, has sophisticated seals at both sides to keep the oil in the tube and the water (aft) out.

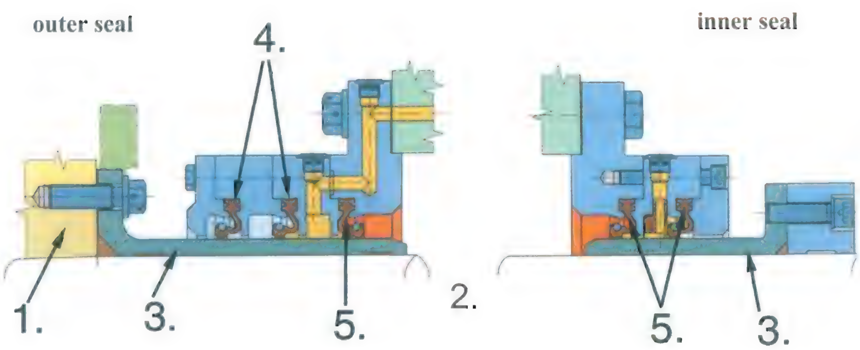
The sealing system at the backside consists of a sealing case and mostly three sealing rings. These sealing rings are made of synthetic rubber. The space between the two bearings is completely filled with lubricant. The aft seal prevents oil from leaking to the outside.



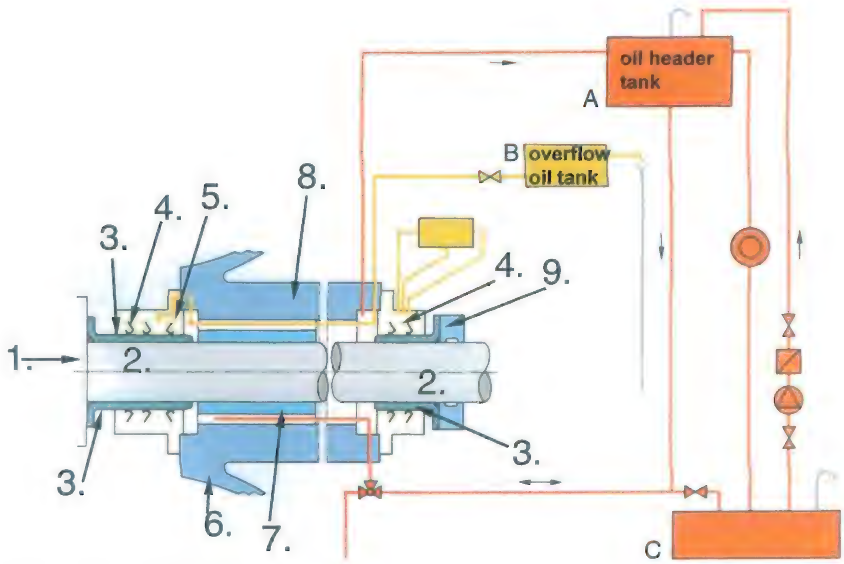
The stern tube is brought into the stern.



Stern bearing and seals



Outer and inner seals



Closed system with lubricating oil

1. Propeller boss
2. Propeller shaft
3. Chrome steel liner
4. Seawater seal
5. Oil seal
6. Stern frame
7. Aft bearing
8. Stern tube
9. Clamped ring
10. Stern tube bearing
11. Fastening at stern tube
12. Fastening at stern tube, where meeting the aft peak bulkhead

The lubricant pressure is only slightly higher than the water pressure. So if seawater should somehow enter the two water seals, the higher lubricant pressure prevents it from reaching the propeller shaft. Seawater could seriously damage the unprotected propeller shaft. The higher lubricant pressure is maintained by a small pressure tank (A), which is placed a few meters above the loadline.

Tank A is part of the main lubricating system, tank B contains lubricating oil for the seawater sealing rings. The oil in the main lubricating system is self-circulating due to the fact that warmer oil rises upwards. Tank C is both the drainage tank and the storage tank. If oil leakage should somehow occur, it is usually limited to small amounts. If not, dry docking is necessary. A chrome steel bush is fitted around both the propeller shaft aft near the propeller and forward at the aft peak bulkhead. The space between the bush and the tube contains lubricant.

The aft chrome steel liner is attached to the propeller boss with bolts, the chrome steel liner of the forward bush is attached to the propeller shaft via a clamped ring. Around both bushes, are non-rotating housings, bolted to the stern tube, with the sealing rings fitted inside.

During dry docking, the position of the shaft, relative to the stern tube, has to be measured, to ensure that the shaft is more or less within a few tenths of a mm, in the same vertical position as when built. This is indicative of the wear of the aft bearing. A special depth gauge, the so-called '**poker gauge**', is designed to measure the position of the shaft. Normally there is no sagging.

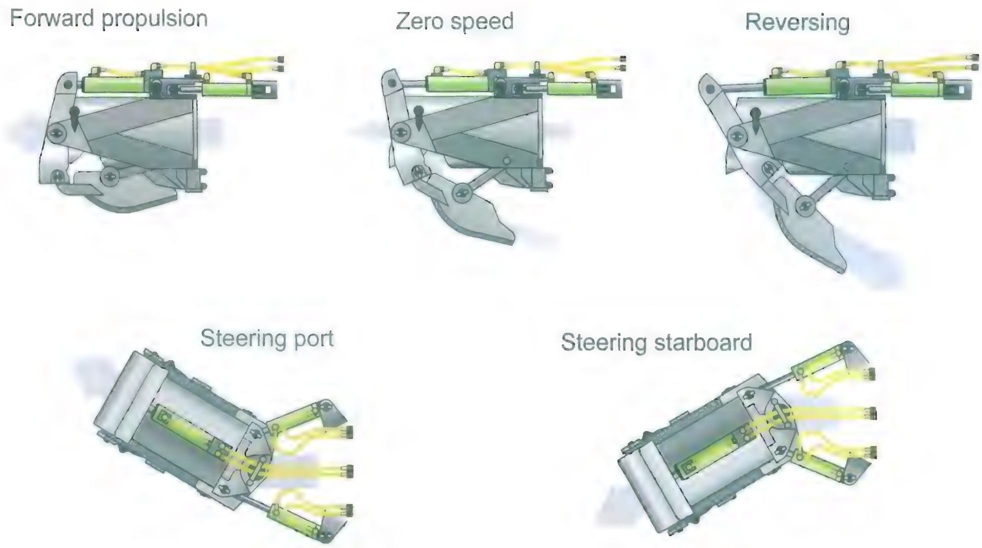
2.8 Water jet propulsion

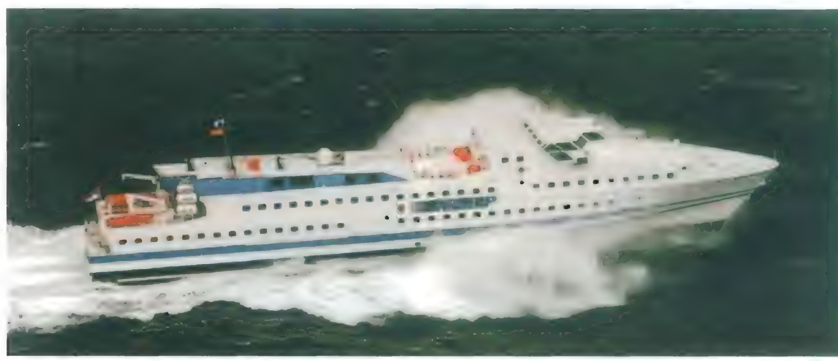
Water jet propulsion is based on the reaction force of a high-velocity water jet at the stern of a (light displacement) ship, blown in aft direction.

The main principles of the water jet are:
- the impeller (propeller) draws in seawater through an inlet, usually in the (flat) bottom
- the same impeller boosts the water pressure for the water flow
  the water is pushed through a nozzle
- the nozzle converts the water pressure into a high-speed jet
- the acceleration of the water flow generates a thrust force that gives the ship its speed
- for sailing astern, the water flow exiting from the nozzle can be reversed in the forward direction with reversing plate(s)

The same principle of a water jet is applied in an aircraft jet engine, but here air is the medium instead of water. The principle is based on Newton's law F = m x a, where F is the force in Newton, m the mass of the water and a is the acceleration of the water.

Water jet with reversing bucket down





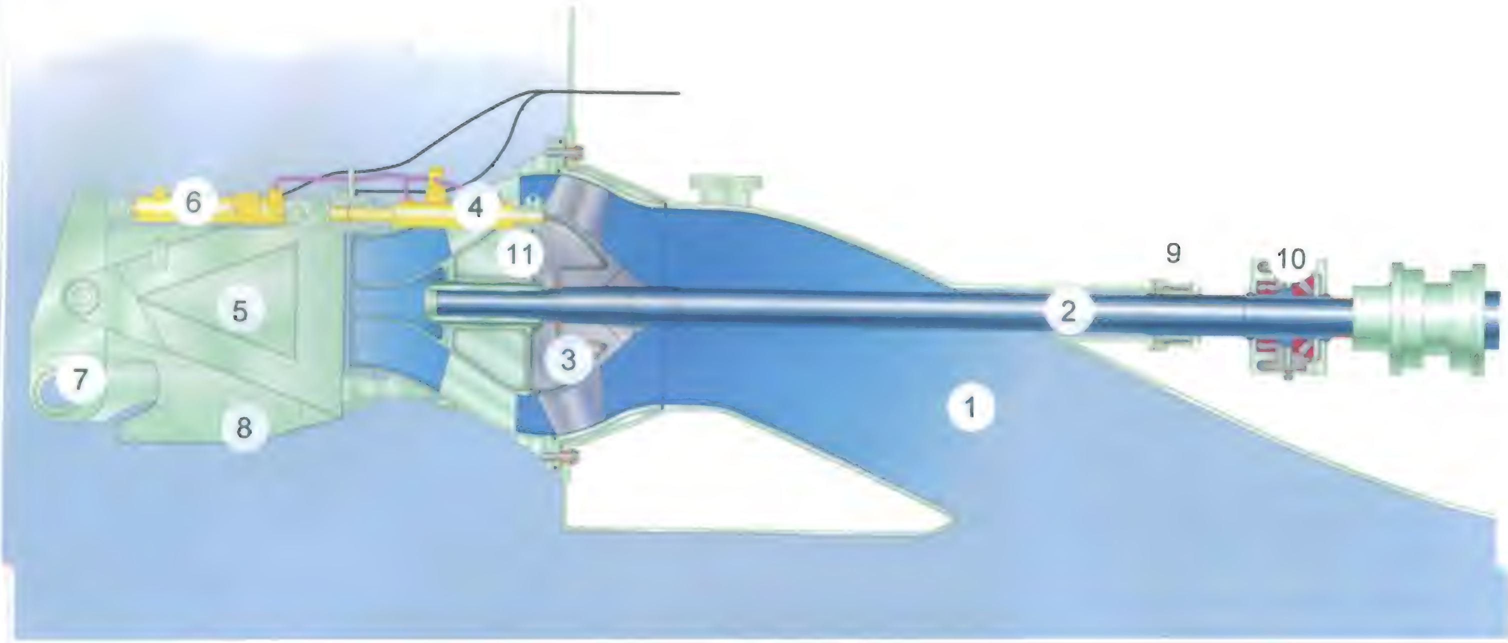
Ship driven by water jet propulsion

Full speed ahead

The water jet has an electronic steering system. This means that the orders from the bridge are immediately processed by micro-processors. This makes it possible for the water jet, engine and gear box to be controlled directly from the bridge.

Along with yachts, many passenger and car ferries, rescue and patrol boats are nowadays equipped with water jets. In 1998 the first cargo ships were built with water jet propulsion. The maximum speed of modern water jets lies around 70-75 knots (approximately 135 km/h). The fastest ferries can reach a speed of approximately 50 knots.

The advantages of water-jets are:
- no rotating parts under water. This makes it safe to maneuvre in shallow waters
  less resistance, especially at higher speeds, because there are no fittings (e.g. the rudder) doesn't protrude below the ship.
- excellent maneuverability capabilities. For instance, a jet-powered ship can navigate sideways
- less sensitive to cavitation than propellers on fast ships
- high propulsion efficiencies of up to 72%



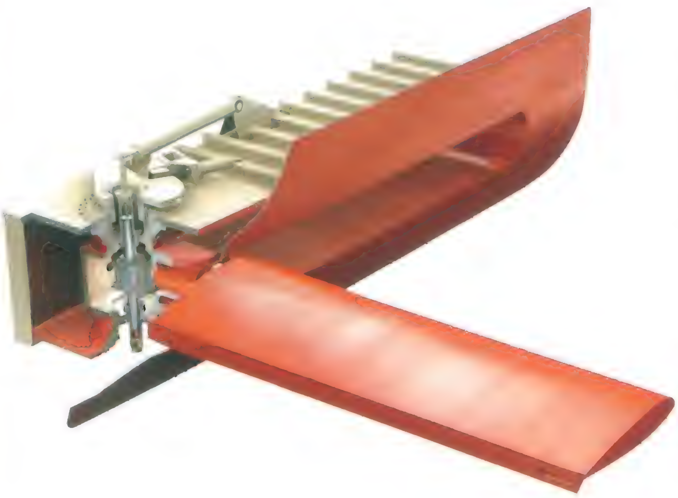
Cross-section of water jet (Wärtsilä Propulsion Jets)

3. Stabilizers

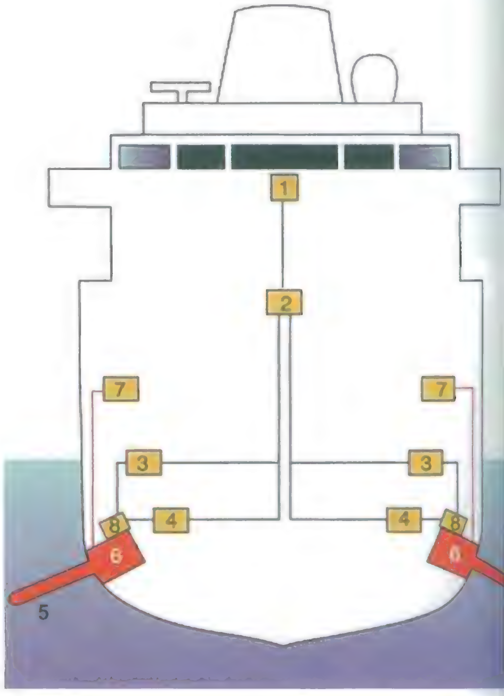
Rolling of a (fast) ship during sailing can be reduced by as much as 80 - 90% by using stabilizing fins. The velocity of the water streaming along the ships side can be used to reduce the rolling, by installing such fins, with a configuration of a flap rudder, in a sideways direction protruding from the bilge strake, which can rotate around a shaft. The maximal rotation angle is up and down approximately 25°. When at an angle similar to the water direction, they produce lifting forces, similar to a rudder, upwards or downwards. When a ship is rolling, water flows along the sides in an undulating way.

The fin is operated such, that at any moment, a reaction force is produced, upward or downward, contrary to the acceleration of the ship side. The angle of attack of the fin profile is adjusted to the flow direction, upward or downward, depending on rolling speed and time and ship speed. The fin is oscillated by a hydraulic piston or vane-type motor. The angle of attack and the rotation speed and period are dictated by a computer, receiving signals from sensors in the rotating shaft, comparing the produced force with the required force and from a gyro. The working force is maximized, but cavitation is prevented. They are in use on passenger ships and yachts for the comfort of people on board, and on ro-ro ships and container ships to reduce the acceleration forces on the cargo. Some heavy cargo ships use stabilizers for the same reason. A decrease in fuel consumption is claimed also. Normal installation comprises one fin on each side, but 4 fins are also installed. The fins can be retracted in order not to stick out from the ship when moored.

1. Inlet
2. Driving shaft
3. Impeller
4. Hydraulic steering cylinder
5. Jetavator, steering part
6. Hydraulic cylinder that alters the direction of the propulsion
7. Reversing plate, can be moved by the cylinder
8. Reverse section
9. Sealing box to prevent water from entering the ship
10. Combined guide and thrust bearing
11. Nozzle



1. Bridge control unit
2. Main control unit
3. Pump motor starter
4. Local control unit
5. Fin
6. Stabilizer machinery unit
7. Oil header tank
8. Hydraulic power unit



4. Rudders

The function of a rudder is to develop a transverse steering force on the aft side of a ship, using the reaction force of the water flowing along the ship (and the rudder). The rudder is usually located in the water flow aft of the propeller. Depending on the type of ship, the area of the rudder ranges from 1.5% to 10% of the underwater lateral area (length x draft).

The rudder should be shaped in such a way that the water flow can be deviated as effectively as possible, in combination with minimal resistance.

Giving the horizontal cross-section of the rudder a wing profile satisfies these two demands. In fact, the rudder is a vertical wing, on which a lifting force is generated by the water flow in the same way as an aeroplane wing, propeller blades and a nozzle get a lift. This is also known as rudder force. The drag should be as low as possible. The lifting force gives a turning moment around the ship's center of displacement, which is what rotates the ship.

For slow-speed maneuvring the rudder should cover the propeller diameter as much as possible in order to make optimal use of the water flow of the propeller.

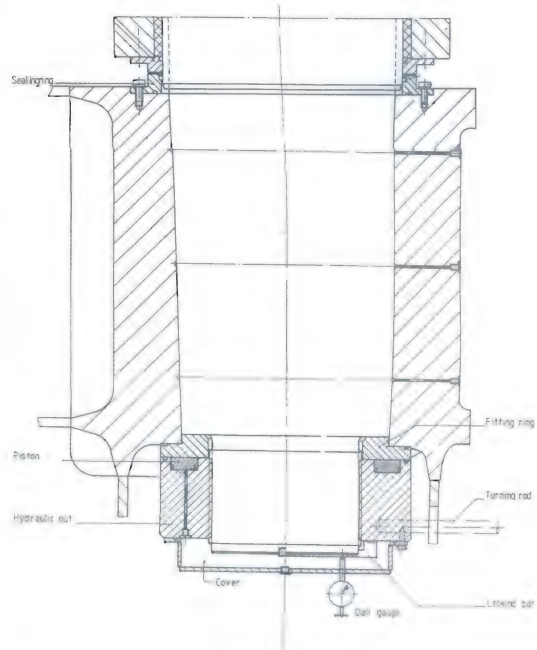
The force that the steering engine must supply depends on the torque (force x distance) that must be applied to rotate the rudder.

This force is the resultant (N) in the drawing. The total moment depends on:
- the position of the rudder stock compared to the point of application of N
- the distance between the rudder stock and the leading edge of the rudder (balance)

When the rudder is free-hanging (spade type), the rudder stock must also be able to absorb the total bending forces of the rudder.

Setting in the heel of a flap rudder

A controllable pitch propeller and a flap rudder of a multipurpose vessel. The underside of the rudder stock can be seen in the rudder.



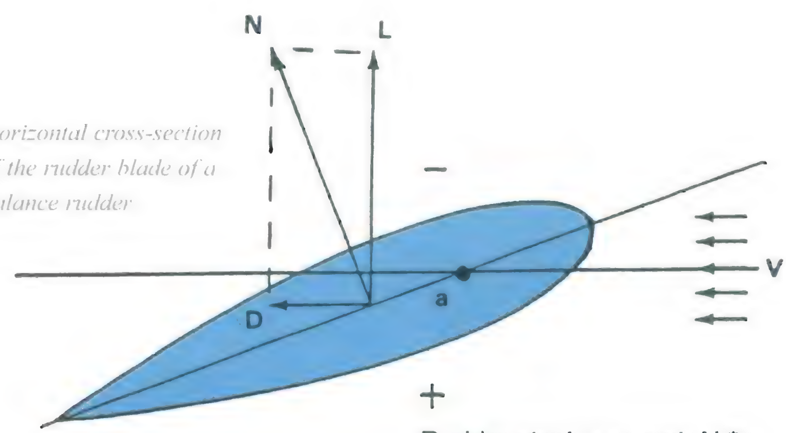
Conical connection between the rudder stock and rudder blade

Depending on the rudder profile, the rudder stock is located 25 - 40% abaft the leading edge of the rudder.

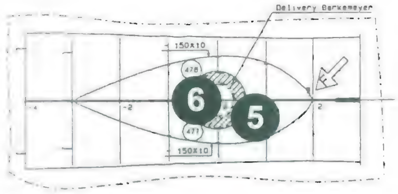
Most rudders are hollow and empty. The inside is stiffened with horizontal and vertical profiles.

The next sections will only describe free-hanging rudders. In smaller vessels (like fishing boats), however, rudders are still supported in specially constructed heels, or in case of mariner rudders at half height (bigger ships)

Horizontal cross-section of the rudder blade of a balance rudder



V = velocity of water flow
L = lift
D = drag
N = resultant force
- = underpressure
+ = overpressure
a = distance between the rudder-stock and the point of application of N

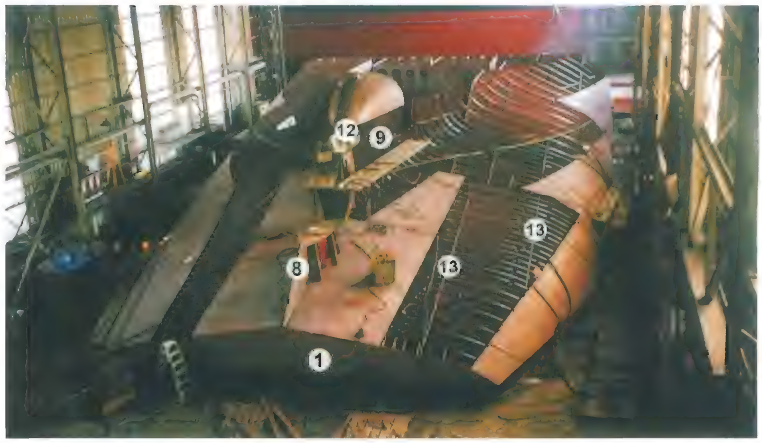


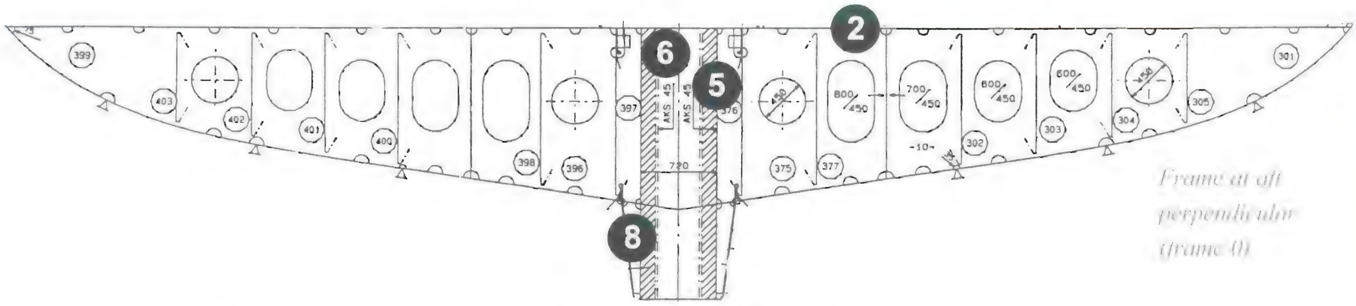
Top view

Construction of part of the lower stern of a container feeder

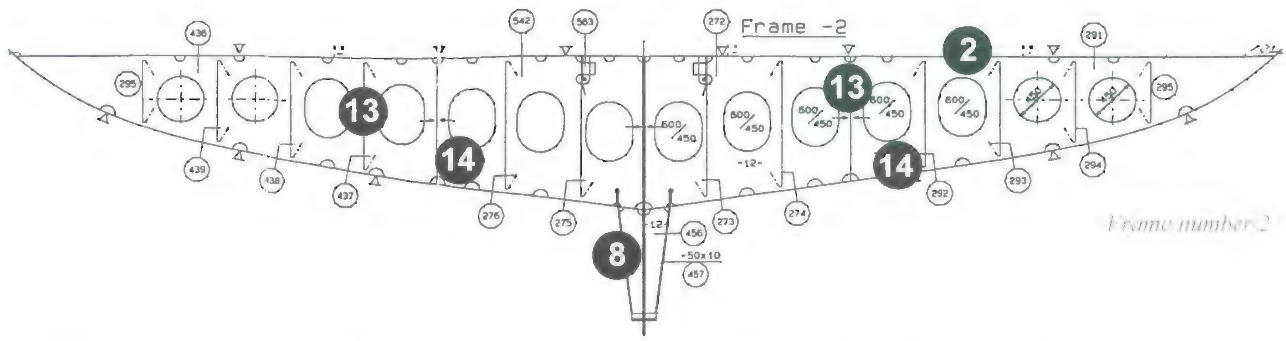
Side view of the ship's centre line

1. Transom
2. Steering flat
3. Aft perpendicular = rudder axle
4. Rudder
5. Rudder trunk
6. Space for the rudder stock
7. Ice protection
8. Rudder dome (deadwood)
9. Stern frame
10. Wash bulkhead on centerline
11. Stern frame center
12. Centerline propeller shaft
13. Side girder
14. Floor plate





Frame at aft perpendicular (frame 0)



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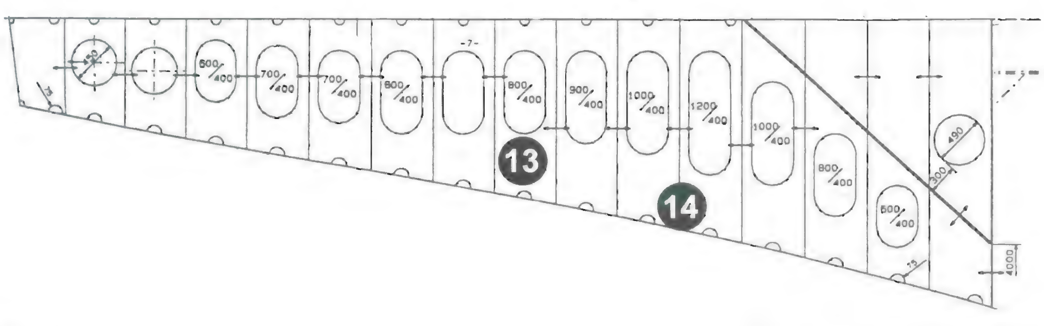


Side girder in stern

Suspension of the rudder
The drawings and photos illustrate how rudders are supported.

The most common rudder types are:
1. spade rudder
2. flap rudder
3. mariner rudder
4. fishtail rudder

4.1 Spade rudder

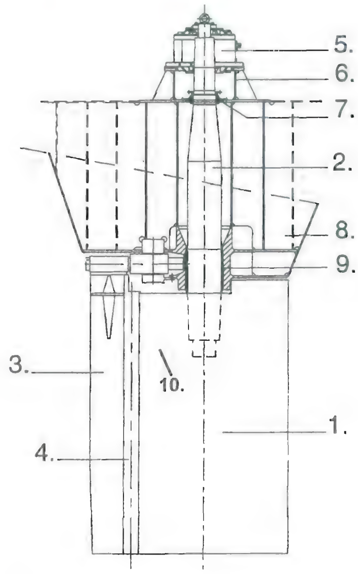
In terms of construction, the spade rudder is very simple because it has no supports. For this reason it is a very cheap rudder and it is widely applied, from yachts to fast ferries and tankers. The rudder usually becomes narrower from top to bottom to reduce the bending moment in the rudder shaft.


A spade rudder on a reefer, freely suspended from the rudder dome

4.2 The Flap rudder

The flap rudder has a hinged flap at the back of the rudder blade. This flap is moved mechanically by the flap guide at the top of the rudder in such a way that the flap's turning angle is twice as large as the turning angle of the main rudder blade. The steering methods of the flap differ per type of flap rudder. When the maximum rudder angle is 45°, the flap has a maximum angle of 90° with respect to the ship. In this rudder position it is possible that 40% of the ship's propulsive force is directed sideways. In combination with a bow thruster such a ship can navigate transversely.


A flap rudder under a large cargo ferry

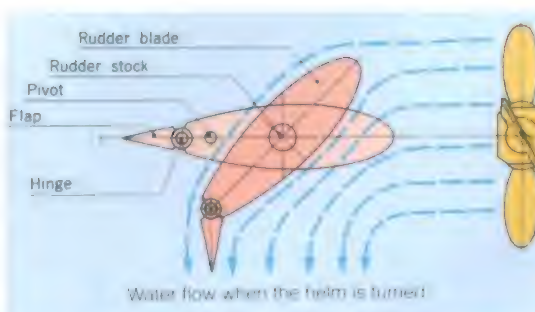


1. Rudder blade
2. Rudder stock in rudder trunk
3. Flap
4. Hinge line
5. Steering engine
6. Steering engine foundation
7. Gland and bearing
8. Rudder dome
9. Steadiment bearing
10. Flap actuator

Advantages of flap rudders are:
- extra maneuvrability (that is, if the main rudder blade is as large as the spade rudder)
  course corrections can be performed with smaller rudder angles This means that the ship loses less speed and therefore consumes less fuel.

Disadvantages are:
- price
- vulnerability
- the larger rudder forces require the rudder stock to be bigger


Flap rudder

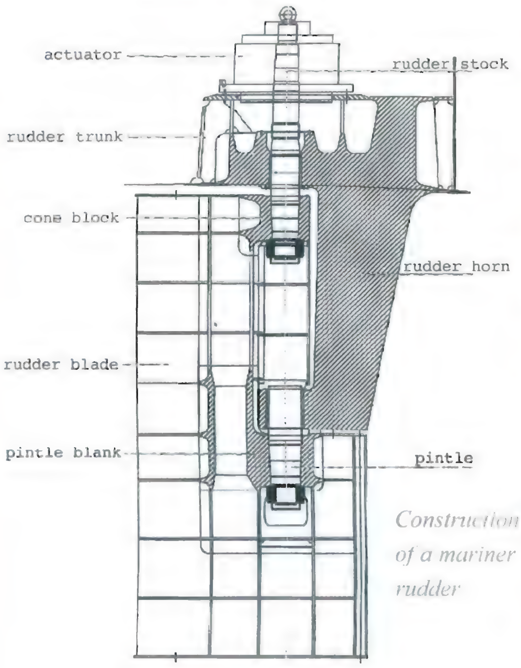


Current flows at maximum rudder angle

4. 3 The Mariner rudder

The Mariner rudder is used on large ships like container ships, bulk carriers, tankers and passenger liners. The rudder horn is integrated in the ship's construction and the mariner rudder is attached to the stern post with the ability to rotate. This results in a robust rudder. Disadvantages of this construction are that there is a larger risk of cavitation at the suspension points and that the cast construction is more expensive.

'Stratus' in dry dock



Construction of a mariner rudder

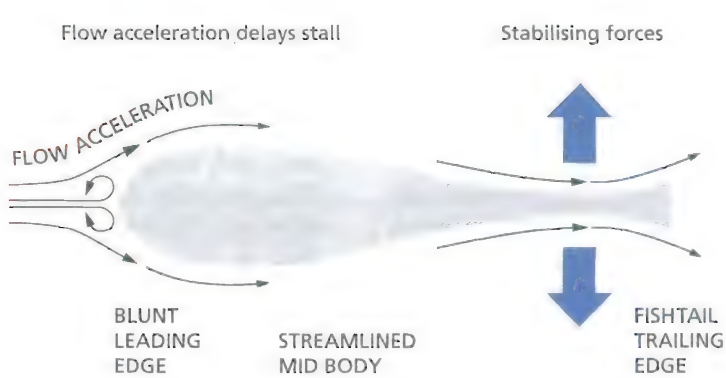
Removal of complete rudder, weight approximately 120 tons

Fitting of pintles to new bushings

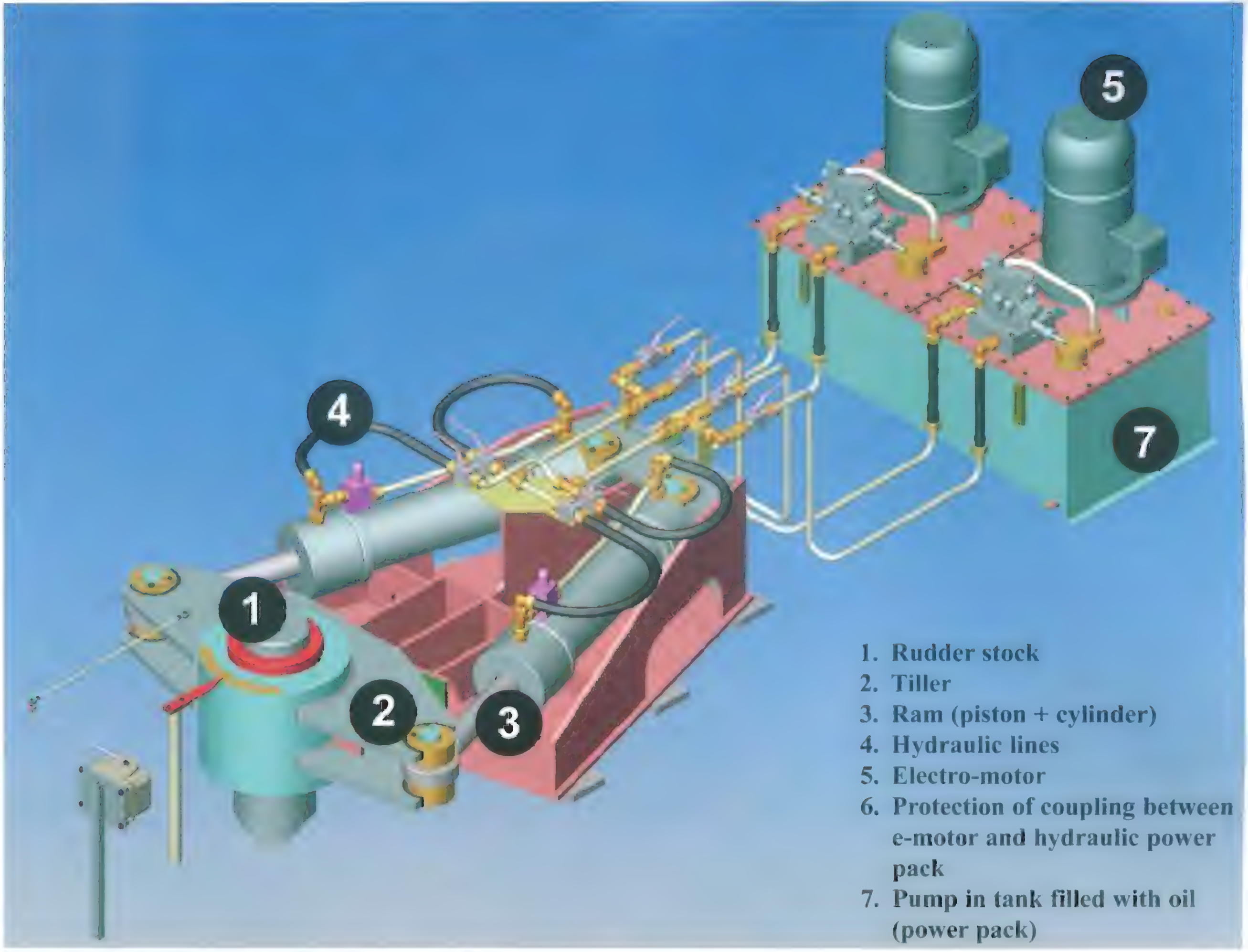
Alignment of rudder and stock in shop

4.4 Fishtail rudder

The fishtail rudder has been developed for ships with a slow speed, less than 14 knots. The after edge of the rudder blade is provided with a friction increase, to give extra drag to the water around the rudder. This improves maneuverability.



Top view of a fishtail rudder



Double-acting cylinders in a ram steering gear of a small vessel

5. Steering gear

5.1 General

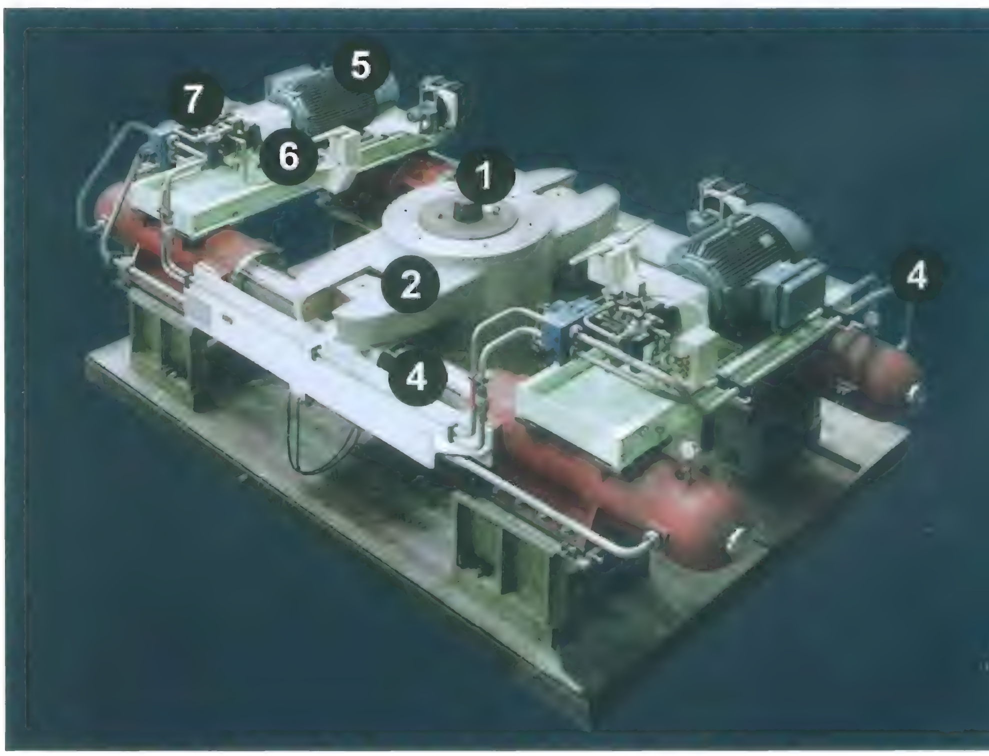
To alter course, the automatic pilot or the helm is used to activate the steering engine, which, in turn, rotates the rudder stock and the rudder. The rudder carrier supports the rudder stock and the rudder. The rudder carrier also functions as a bearing around the rudder stock and seals the rudder trunk to prevent seawater from entering the ship by a gland.

SOLAS demands that every steering engine be equipped with 2 sets of pumps with separate power supplies, and, consequently, also 2 servo sets, serving the hydraulic pumps. Both the ram and rotary vane steering engines operate by hydraulic power. Both types of steering gear are equally common in shipping. The magnitude of the steering or rudder moment is expressed in kNm (kilo-Newton meter). In general the greatest rudder moment occurs at 30°-35°.

5.2 Ram steering gear

In ram steering gear, the rudder stock is rotated by a tiller that, in its turn, is controlled by rams. A ram consists of a cylinder and a piston, the piston being moved by hydraulic pressure. The tiller and the rudder stock are often linked by a conical connection.

Ram steering gear can have 1 ram, 2 rams or 4 rams. If, in the case of one or two rams the cylinders are double-acting, the steering engine can still operate through one of the cylinders when the other one fails. A 4-ram system can be split in two and two for the same reason. This is a requirement of SOLAS.



Ram steering gear of a large ship

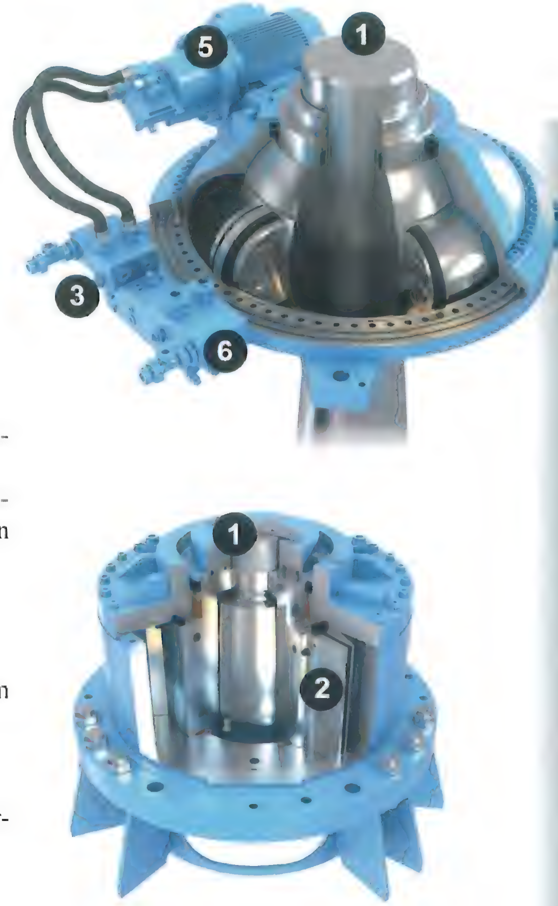
5.3 Rotary vane steering gear

A rotary vane steering engine consists of a fixed casing, with a rotor to which wings are attached inside the casing. The casing is provided with two similar fixed wings as on the rotor. This arrangement divides the house into four chambers, two high pressure and two low pressure ones. A valve block directs hydraulic oil at high pressure into the chambers simultaneously, pushing/rotating the rotor and subsequently the rudder. If the rudder is rotated to the other side, the high pressure chambers become low pressure chambers and vice versa. The rudder stock is located in the center of the rotor; the rotor is pressed onto the conical section of the rudder stock. The wings and the fixed division blocks are provided with spring-loaded plates which are the seals between the high and low pressure oil chambers.

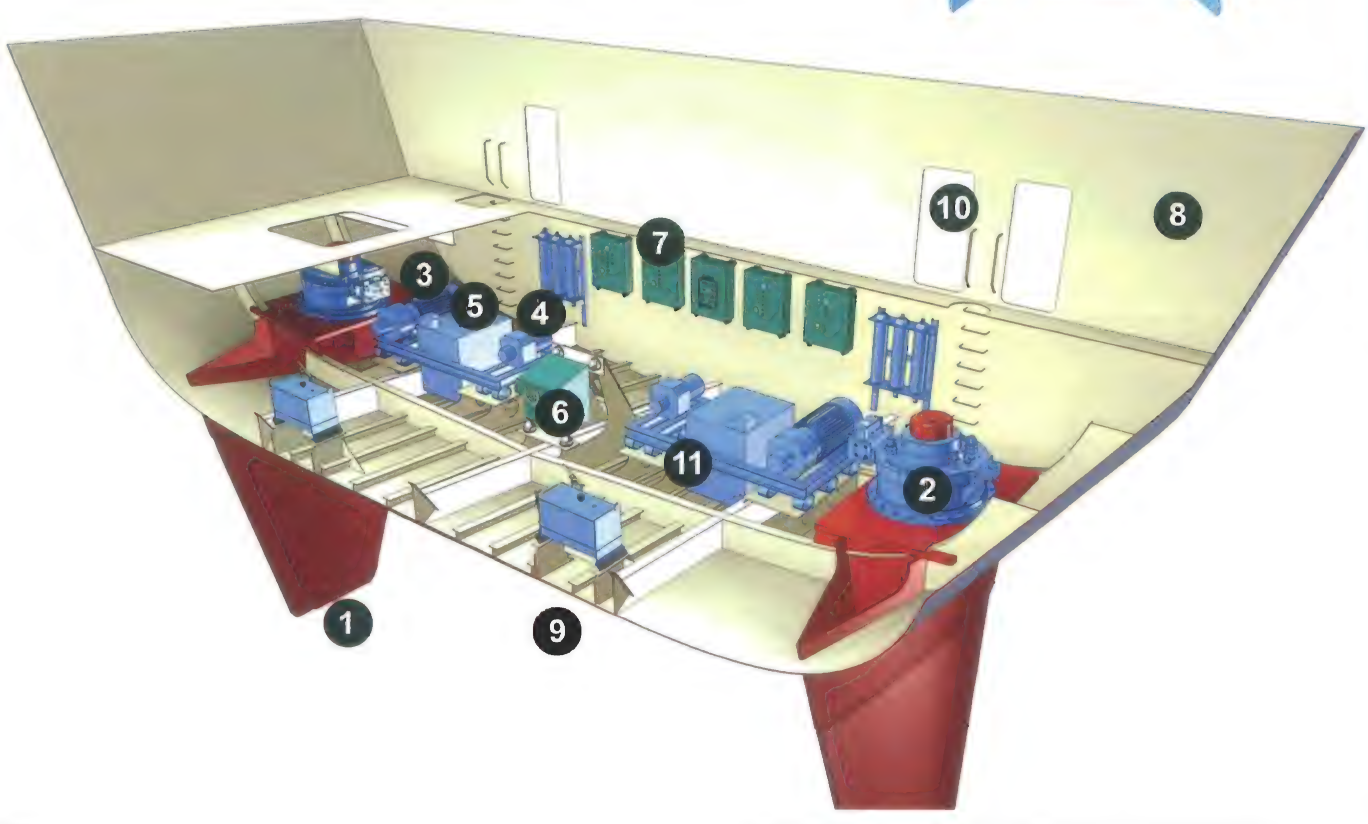
Advantages of a rotary vane steering gear engine over a ram steering engine are:
- takes up less space
- easier to build in
- has an integrated bearing
- has a constant rudder moment

Disadvantage:
repairs are quite complicated

Rotery vane:
1. Rudder stock
2. Rotor with wings
3. Fixed division blocks with oil lines
4. Chambers (filled with oil)
5. Electric motor
6. Hydraulic pump



Below:
1. Rudder
2. Rotary vane steering gear with valve block
3. Electric motor with main hydraulic pump
4. Power units (to supply the hydraulic power to operate the valves in the valve-block)
5. Hydraulic oil tank
6. Emergency maneuvring console
7. Starter boxes electric motors
8. Bulkhead between engine room and steering gear room
9. Bottom
10. Entrance from engineroom
11. Hydraulic oil lines for maneuvering and cross connections



Flap rudder, disconnected from rudder kingpost, being lowered in dry dock. Note the welded flap securings.

CHAPTER 13

Electrical Installations

Engine control room semi submersible crane vessel 'Balder'. At the left the new installed controls for the new generator sets.

1 Preface

This chapter explains some basics about electricity and how a ship's electrical installation is designed, installed, commissioned and tested.


Lightning, always an impressive waste of energy

Electricity is a clean way of energy transport and exists of two basic types:
- Direct Current (DC)
- Alternating Current (AC)
  Rotating Alternating Current is a further development of Alternating Current.

A distinction has to be made between "current" and "Voltage". The principle of operation of electricity is often made understandable to compare it with the behavior of a liquid in a system. In that liquid model current is reflected by flow, and Potential or Voltage is reflected by pressure. Potential (or Voltage) is measured when the system is at rest. It is measured in Volt. Current is a moving charge, the transport of an electric charge from a high voltage to a lower Voltage, and is measured in Ampere.

1.1 Direct Current (DC)

DC is created in nature as static electricity, leaking in large quantities to earth as lightning or as a simple spark when a person touches an earthed metal part when walking on a synthetic carpet.

The energy transformation creating direct current can be static electricity, a chemical process such as in a battery, heat in fuel cells or rotation in a dynamo or generator. The ultimate transfer of static electricity is lightning. Too much and too fast to store, but an impressive view.

Direct Current is a wrong expression. Direct Voltage would be a better name because a dynamo creates Potential or Voltage. The user decides the current.

Direct Current is normally a two-conductor system, where one conductor is at a constant voltage and the other is earth. Through a user, the Voltage drops to earth, transforming the electricity into light, movement or otherwise. The charges move constantly, from the high Voltage to earth.

Direct Current can be stored in batteries, and can later be used when needed; this gives the opportunity to have difference in capacity of generation and capacity of storage and capacity of use. In modern ships DC systems are only used in small systems: systems for the temporary use such as emergency lighting, security and alarm systems.

A disadvantage of direct current systems is that the Voltage from the generator which is basically alternating is transformed into Direct or constant Voltage by using collectors (commutator) and carbon brushes, which

require extensive maintenance, and becomes more complicated when the capacity becomes larger.

Also the constant magnetic field created by Direct Current in a motor has to be transformed into a rotating field by using a collector and brushes.

Brushes on collectors continuously produce sparks causing wear of the collector surface. Brushes have to be renewed regulary and the collector surface has to be smoothened. The switchgear is expensive and maintenance unfriendly.

Generator capacity is expressed in Amperes, battery capacity in Amperes per Hour. The charging period of a battery can be different from the discharging period. The charging period depends on the capacity of the charger and the discharging period results from the consumption of the user. Energy, stored in a battery can be used later for a shorter time with a higher current or for a longer time with a lower current than the charging current needed to fill the batteries.

Conventional Submarine

The power system of a conventional diesel electric submarine consists of diesel generator sets producing DC power when at surface or at snorkel depth, batteries and an electric propulsion motor. This power can be distributed to charge the batteries and/or power the propulsion motor.
Conventional diesel electric submarines use the principle that the charging current of a battery can be different from the discharge current.
During sailing at the surface the diesel generators produce electricity, which is partly stored in batteries as chemical energy Direct Current and partly used for propulsion.

Collector or Commentators: Part of motor or dynamo, where the current is transferred from the external connections to the rotating part of the generator or motor. The actual transfer is done via carbon brushes. Current is also switched into opposite direction so changing AC into DC and changing stationary magnet field into rotating magnet field.

A battery consists of two or more metals, in a conductive (mostly acid) environment. The metals dissolve, whereby ionizing, and develop a difference in potential between them. Lead acid batteries are the most commonly used type; the more expensive but longer lasting Nickel Cadmium batteries use a base as conductive.

A hybrid car is driven by a combination of an electric motor and a petrol or diesel engine with the engine not only driving the wheels but also charges the batteries through a generator. With the electric motor the car can drive on the battery capacity with combustion engine stopped. The battery capacity can also be used to obtain a higher speed with the engine and electric motor working together. The energy resulting from braking can also be retrieved into the batteries.

A transformer converts AC Voltage into another AC Voltage with the same frequency as the input Voltage. Transformers, convertors and rectifiers do not create electrical energy so the product of voltage and current of the input is about the same as the product of voltage and current of the output

A converter converts AC input Voltage and frequency into AC output Voltage and frequency, where input and output frequency can be different.

A rectifier converts AC input Voltage into DC output Voltage

The energy stored in the batteries is later converted into electric current which drives the electric motors for the ships propulsion during submerged operation.

Hybrid auto cars also use a similar principle. When the battery is full and the car runs slow the electric motors are supplied from the batteries. When the car is running faster the engine starts and drives the car also charging the batteries. For maximum speed the electric motors and the engine are working together

Battery capacity (the product of current and time expressed in Amperes per Hour), depends on the battery type. A battery for starting a diesel engine needs to discharge at a high rate in a short period, where batteries for emergency lighting need to discharge at a low rate, during a long time for instance 18 to 36 hours.

DC machine

Collector and brushes of a large DC machine either motor or generator (03B)

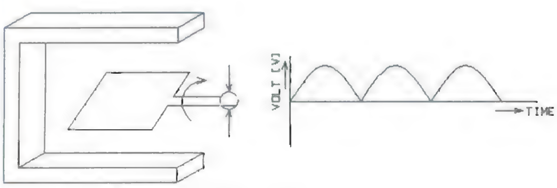
Analogue an electric motor can supply more power during a short period or less power during a longer period.

The advantages of a conventional Direct Current System are:
- Simple working together of more generators (Parallel-Running)
- Simple storage of energy in batteries.

The disadvantages of DC Systems are the generators and electric motors with brushes and complicated switchgear.

New technology has provided the possibility to overcome the disadvantages of DC: Brushless alternating current generators with built-in-rectifiers supply Direct Current. Motors made for rotating alternating current can be supplied from a DC supply when the Direct Current is converted into Alternating Current by DC/AC convertors.

Principle of a DC machine either generator or motor.



DC Machine either generator or motor

Simplest form would be a rotating winding within a magnet. The winding receives AC electrical voltage and when the winding has turned 180° the collector changes polarity and the output is a pulsed DC

For a DC motor the DC voltage to the rotor is reversed every half turn and so the magnetic field of the rotor so that the torque remains in one direction.

For bigger machines an electric magnet rotates within a winding generating alternating current. As the magnet is energised by electric power through a set of brushes and a collector and the magnetic field is reversed at every half turn the stator voltage is a rectified DC voltage

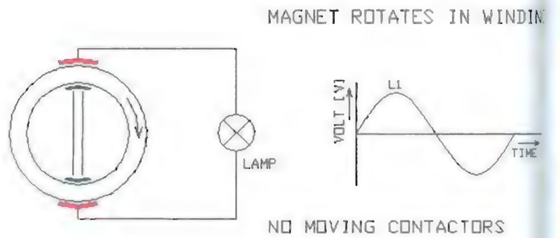
1.1.1 Uninterrupted Power Supply (UPS)

A modern way of using DC, is an Uninterrupted Power Supply (UPS) unit. Such a device is a combination of a battery charger, transforming alternating current into direct current, which is stored in a battery.
The units often are used as power supply-units for computers, where power interruption, or low-voltage can lead to loss of information or to the stop of a program. Depending on the type of system this can lead to undesired or dangerous situations. The UPS-units have a limited capacity, often not more than half an hour. Within that period the normal power supply has to be back or the computer system has to have saved the information and safely shut down the programme.

1.2 Alternating Current (AC)

Single phase alternating current is a two conductor system, where one conductor has a positive charge followed by a negative charge. The sinus shape is the ideal graph of an alternating charge against time. The other conductor is earth.
The number of complete sinus curves (periods) per second is called frequency. The energy charges are moving in both directions along the charged conductor, one way during half of the period, and in reverse direction the other half of the period.

> Alternating Current is a sinus shaped Voltage generated into a winding by a rotating Direct Current energized or a permanent magnet. The simplest form is the bicycle dynamo where a permanent magnet rotates within a winding generating Alternating Current Voltage proportional to speed. Also the frequency is proportional to the RPM of the magnet. For a simple light dynamo it is not so important that the voltage increases with the speed it only influences the life time of the bulb. For more sensitive equipment such as light emitting diode lamps the voltage has to be stabilized with a control circuit



No moving contacts

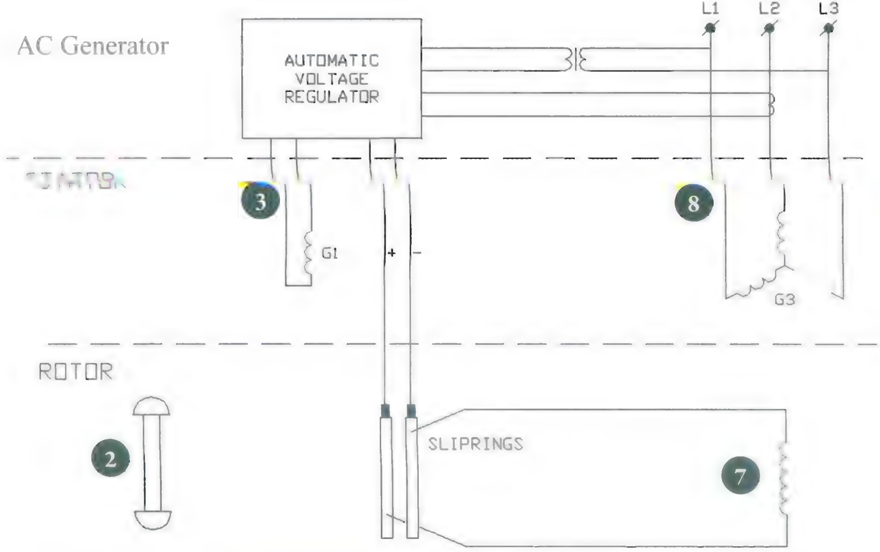
Alternating Current is created in generator. In nature, contrary to Direct Current, it does not exist.
Principle AC generator. Here no switching collectors but slip rings collecting continuous the Voltage from the rotor. Coil rotating within a magnet creates electricity; after 180 degrees turn the Voltage goes negative and so on. Whether the coil is turned within a magnet or a magnet is turned within a coil does not make any difference.

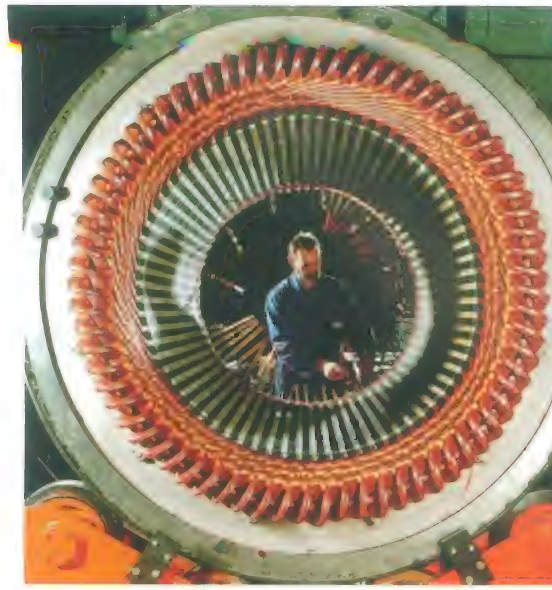
The principle diagrams show the basics of magnetism, coils rotating within a magnet generate Voltage, energized coils within a magnet creates torque. Principle DC generator and Principle AC generator is very similar

1.2.1 AC-Generators

From the basic bicycle dynamo into a single phase AC generator it is a small step.
The Voltage is to remain constant over a load range to protect the consumers. For instance a 10% over Voltage to a simple light bulb gives 20 % more light for a short period but also 20% less life time.

A 10% under Voltage gives a clearly visible change in light of Incandescent bulbs. For fluorescent tubes the light output remain at the same level but halogen lights show a big difference in lighting level. Life time is inverted proportional to Voltage. Thus Voltage control is required. To create a larger quantity of electric power, the permanent magnet rotor, which is limited in strength and size, has been replaced by an electric-magnet rotor. This is a rotating coil where a magnetic field is created by a DC current from outside through the coil, via sliding contacts called slip rings at the rotating shaft. Again these kind of contact i.e. slip rings and brushes, are requiring much maintenance.




Stator of a large generator during production


Sliprings of a large generator during maintenance

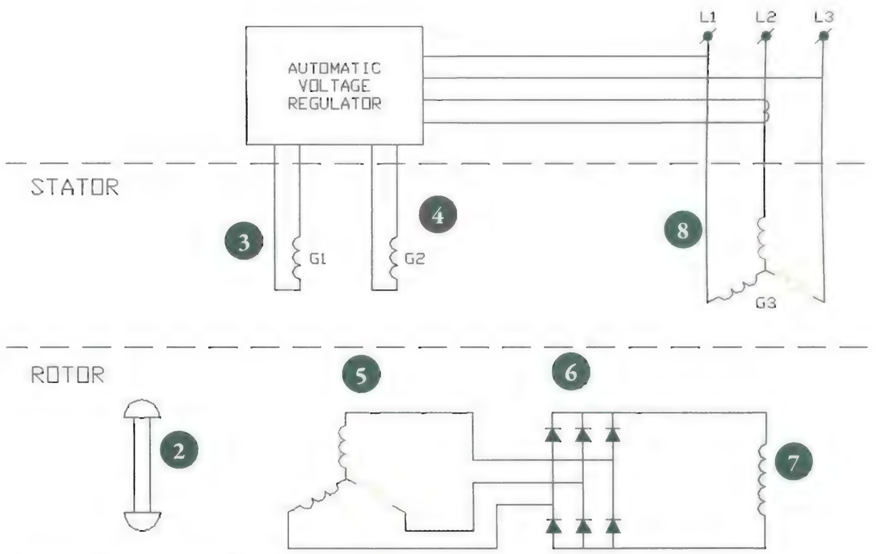
Sliprings are rings fitted on the rotor connected to the rotor windings. The sliprings are supplied with DC power through the fixed carbon brushes from the Automatic Voltage regulator (AVR)

Instead of the sliprings and the brushes and the maintenance required the exciter has been developed.

The exciter is a rotating transformer with the primary winding fixed and with the secondary winding fitted on the same shaft as the final generator. The fixed magnet is an electromagnet energized by Direct Current Voltage. The Direct Current Voltage is controlled by the Automatic Voltage Regulator (AVR).

In the secondary winding the exciter rotor winding (5) an Alternating Current Voltage is generated. This Voltage in the rotating coil is rectified (made Direct Current through rectifiers or diodes (6), which only allow current in one direction). This Direct Current is fed into the rotor poles of the generator (rotor 3) creating strong electro-magnets. (7)

The initial electricity to start a shore-generator comes in general from an outside source.
To make a ships generator independent from any outside source, some permanent magnets (2) are fitted on the shaft (rotor-1) creating Alternating Current in a small fixed primary starting coil(3)
This coil supplies the Automatic Voltage regulator AVR with the start up electricity. This is rectified and controlled in the AVR and the DC output feeds the fixed primary winding of the exciter. (4)
The AVR has also inputs from voltage and current transformers and controls the voltage over the total range of the generator. The input from the current transformers allows the AVR to maintain a steady short circuit current for a short period to enable the switchgear to detect a fault and switch off AC Generators using a strong permanent magnet as rotor inside the stator developing an Alternating Current with frequency and Voltage proportional to the rotating speed are becoming to be used again.



Brushless rotating current generator

2. Permanent magnet
3. Primary coil, producing Alternating Current.
4. Stator exciter winding, alternating Current from 3, rectified in AVR makes this coil (4) a magnet.
5. Exciter rotor windings, producing a stronger Alternating Current.
6. Rotating diodes rectify AC into DC
7. DC energizes rotor poles (7) to strong electro magnets
8. Rotating strong electromagnets produce 3 phase rotating voltage into stator windings (8)

The new generation of permanent magnets is so powerful that they can create very high voltages in the stator. With the 3-phase rotating current rectified directly in the machine the output is Direct Current with a Voltage in proportion with the RPM. This makes these generators suitable as battery chargers and the DC current can be stored in batteries without further equipment.

1.2.2 Switchgear

Alternating Current allows for simple switchgear, as during each cycle the voltage goes from zero to the maximum and back to zero, and an arc that develops when a contact is opened to stop the current, extinguishes itself at the moment of zero voltage. When the distance between the contacts is still relatively small, the arc may ignite itself again. Sometimes this is a repeating action during the opening of a contact, till the distance is too wide for the arc to ignite again.

This interrupting process can be improved by designs which extinguish the arc by air blow or arching chambers, absorbing the energy of the arc. In addiction fast switchgear has been developed to widen the distance between the contacts so much, that the arc does not ignite again. They are called limiters, and allow application at higher currents.

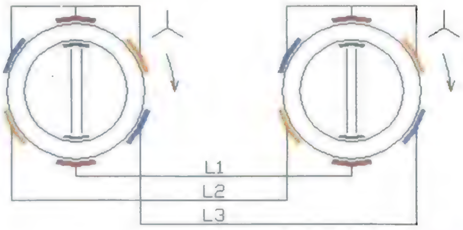
For rotating Alternating Current the same principles are applicable.

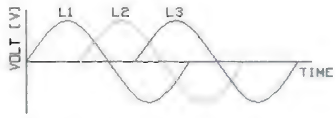
Alternating Current is a very suitable transport medium for energy transport for lighting, heating, and switching signals. As soon as rotation is involved, an auxiliary winding is needed to define the direction of rotation. Small electric motors therefore have an auxiliary winding to define starting in the proper direction.

The early Alternating Current generators were single phase. This means that the two ends of the stator coil were developing voltage one by one. Single phase Alternating Current charges the electric magnets in a motor twice per revolution, reversing each time the north and south pole of the magnet.

1.3 Rotating Alternating Current

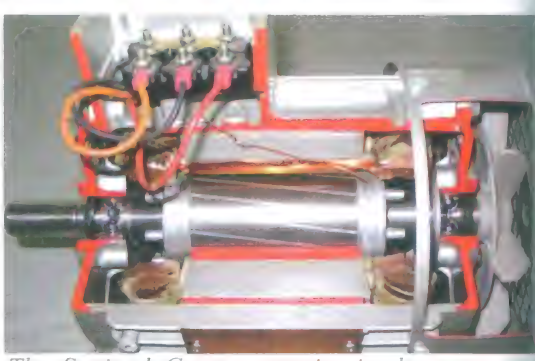
The next logical step is the 3-phase Alternating Current system, or the Rotating Alternating Current System.





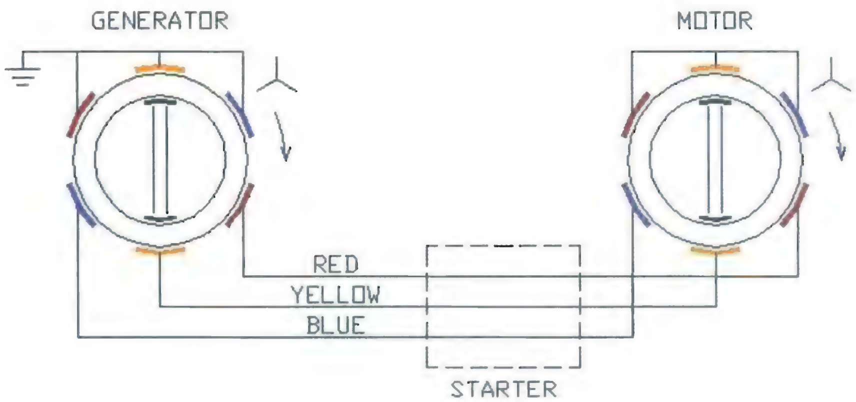
Rotating current system

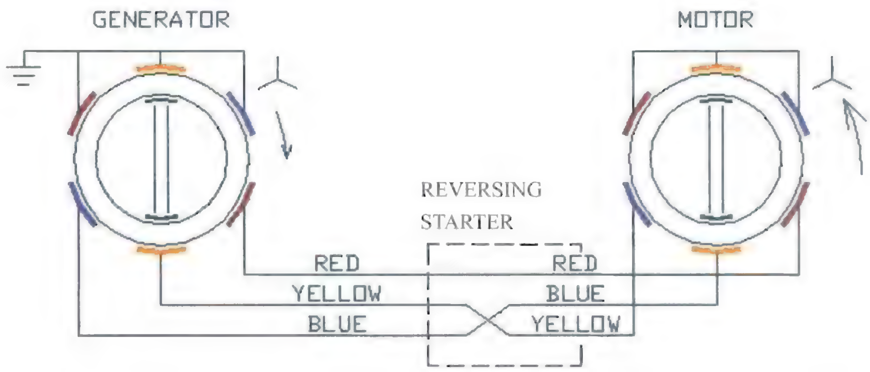
The DC magnet of the generator now rotates inside a stator which consists of three windings, spaced 120 degrees from each other, and creating three Alternating Current currents in sequence of the windings. This rotating current makes it possible to use an electric motor without a collector and brushes, with a stator which has the same 120 degrees spaced windings. This rotor has been simplified into a cage of short circuited rods, instead of windings, which is called a squirrel cage rotor.



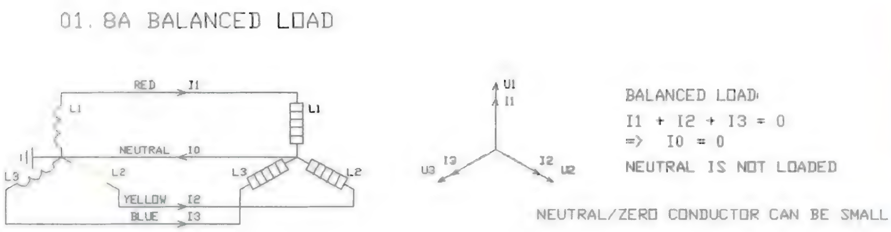
The Squirrel Cage motor is simple and maintenance free. No collector, no carbon-brushes and thus no maintenance.

Reversing the direction of rotation of the rotor is done by changing two phases in the stator, resulting in changing the direction of the driving magnetic field.



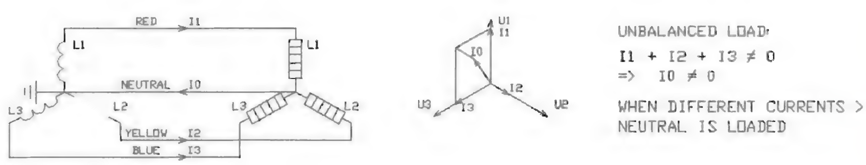


A further advantage of this 3-phase system is that when the load is equally divided over the phases, the sum of the three phase currents is zero. The cable between the star point, where the windings are connected, the so called star point conductor can be deleted or reduced. This system is widely adopted on ships and ashore.



Equal devided load

As the sum of the currents is not zero the neutral or star point conductor is loaded. In general the load is divided as far as possible equally over the three phases and the star point conductor is normally half the size of the phase conductors.



Not equal devided load

For lighting, normally one phase out of the three available phases is used against neutral/zero/. The voltage between phases is 400 Volt, and the voltage between one phase and zero/earth is 230 Volt. No transformers are needed between the three phase net, which can be used for motors, and the lighting net.
When the lighting net is extensive the points are distributed equally over the three phases, resulting in similar load per phase. Ashore the number of lighting points is so enormous that the phases are equally loaded. On board of a ship, the differences can be considerable.

2 Electrical installations

The three principal properties of electrical installations in ships are complete, redundant and the capability to function together on the limited space.

2.1 Complete

Electric installations in ships are a very complete part of electrical engineering, as they cover the complete spectrum from power generation, via distribution and switchgear to all consumers. All types of automation, communication (internal and external), nautical- and navigation systems are included.

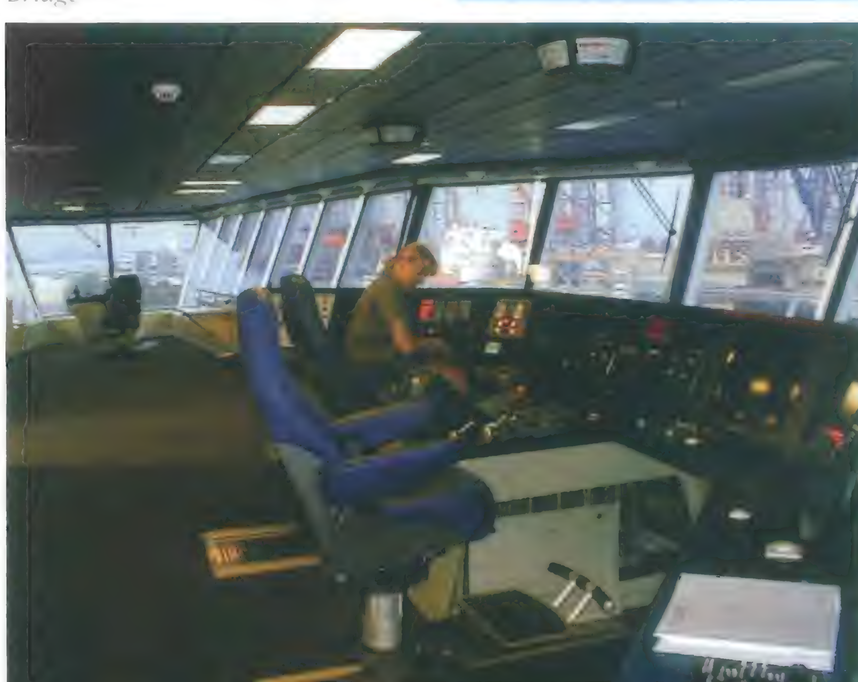
2.2 Redundancy

The basic difference between a ships electric system and a shore electric system is that the ship has to be self supporting, at least till the next port of call. This means that for essential equipment there is spare equipment installed onboard. Alternative and for less essential equipment there shall be spare parts and also people who are able to repair each component in case of failure. The required quantity of redundancy is based upon the purpose of the ship and on the voyages the ship is intended for.

A pipe layer vessel where a power failure could lead to losing of the laid pipe will have more generators standby and connected to two separated switchboards than a simple harbour tug. A ship for short voyages, coastal, or inland, can do with less spare equipment than a ship which has to stay at sea for several months or even a year.

Redundancy is the quantity of spare systems and parts which have to be onboard of a ship to ensure continuity in operation in case of a defect of a component or of a system. This means that the ships staff has to be able to perform repairs at see up to a certain level, and the necessary spare parts have to be on board. (This does not only apply to the electrical systems). Duplicated equipment can be serviced by shore based people (Shore based Maintenance). A single main engine as is often fitted can continue to run with a cylinder out of action at reduced load until next port or can be repaired by the crew at sea with the parts available on board.

Bridge



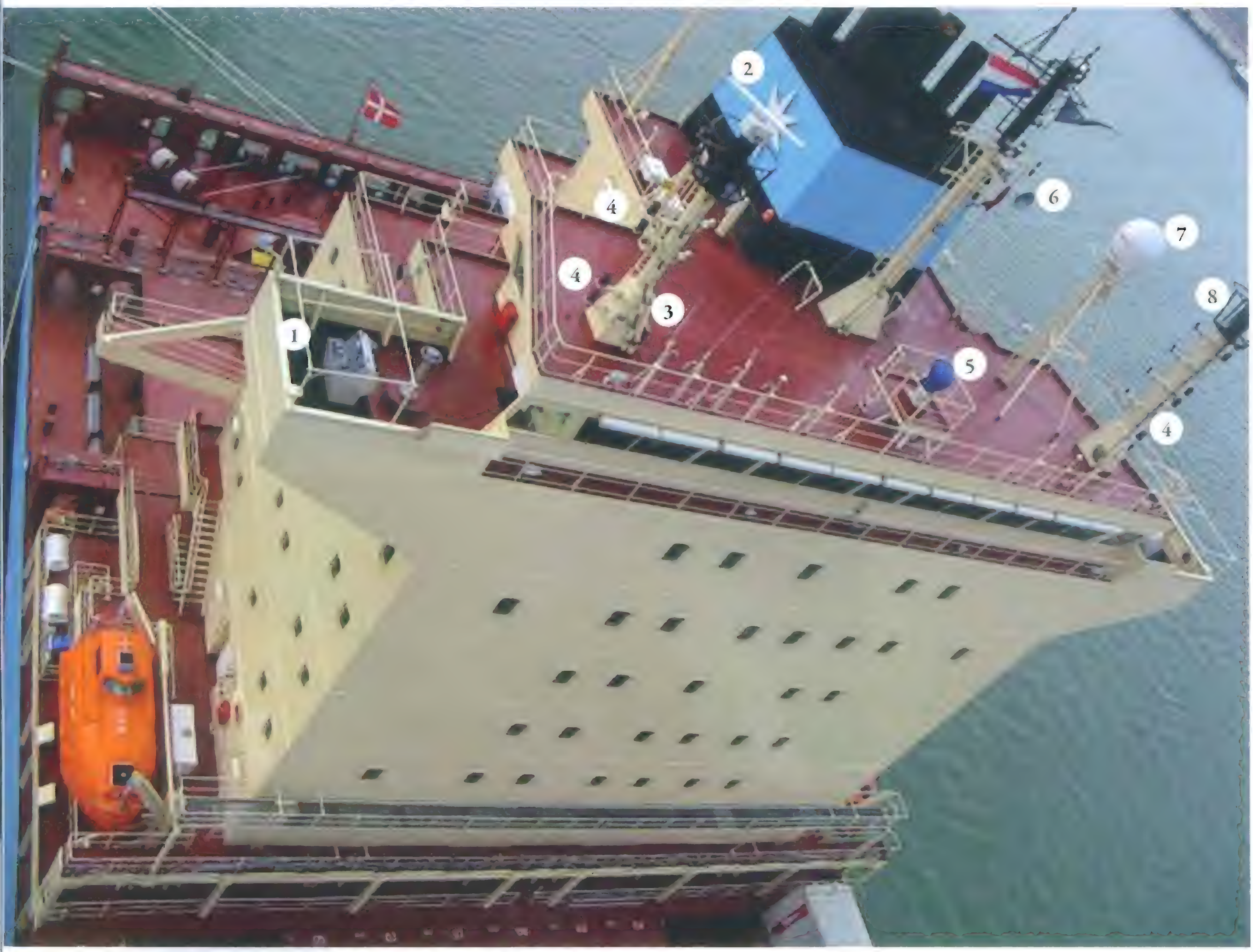
2.3 Electro Magnetic Compatibility (EMC)

EMC or Electro Magnetic Compatibility is the capability of equipment and systems to operate on board together without undesired influence to each other as well as function within the ships environment.

Due to the space limitations on a ship EMC is more difficult to obtain. The completeness of the installation so incorporating power generation, distribution, transformation, high power convertors etc. with all kinds of consumers and automation and communication equipment makes it even more complex than ashore.

The requirements for navigational and nautical equipment have been defined by TC 80 in the IEC standard IEC 60945. Navigational and nautical equipment that is type approved according above standard is suitable for the ships environment. Further sensitive equipment is certified to operate properly within the defined environment and disturbing equipment is tested not to radiate or conduct signal values above the accepted limits. Al this is only valid for the equipment in the same conditions as when tested. So taking equipment out of it's housing or connect it with a different type of cable will ruin the performance.

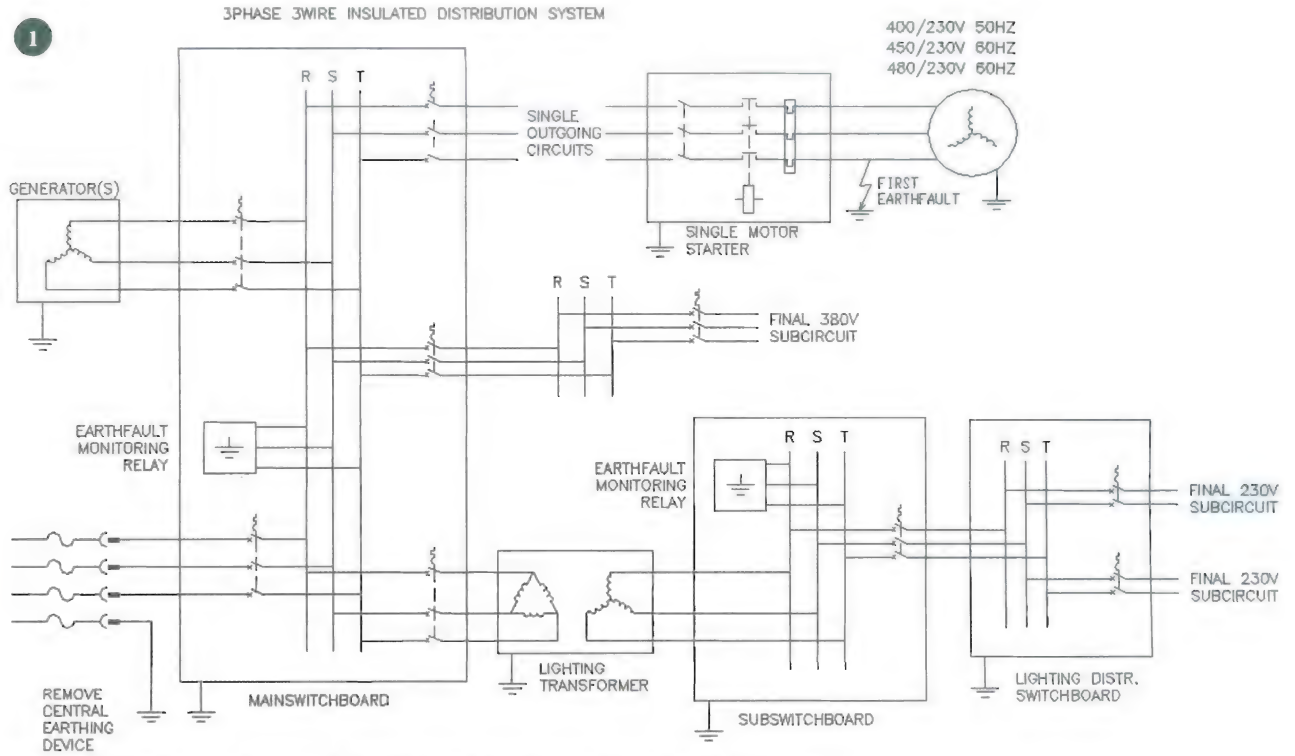
Sensitive equipment as communication receivers, microprocessor systems and disturbing equipment as radio and radar transmitters and also high powered semi-conductor drives, all together in a limited space, requires a study for Electro Magnetic Compatibility (EMC). To get EMC separation and shielding of cables (and components) whose signals can interfere with each other as well as an analysis of the power supply quality and eventual filters is required for a good functioning installation.
Also the location of antennas on the topdeck is part of the EMC study.
See 5.



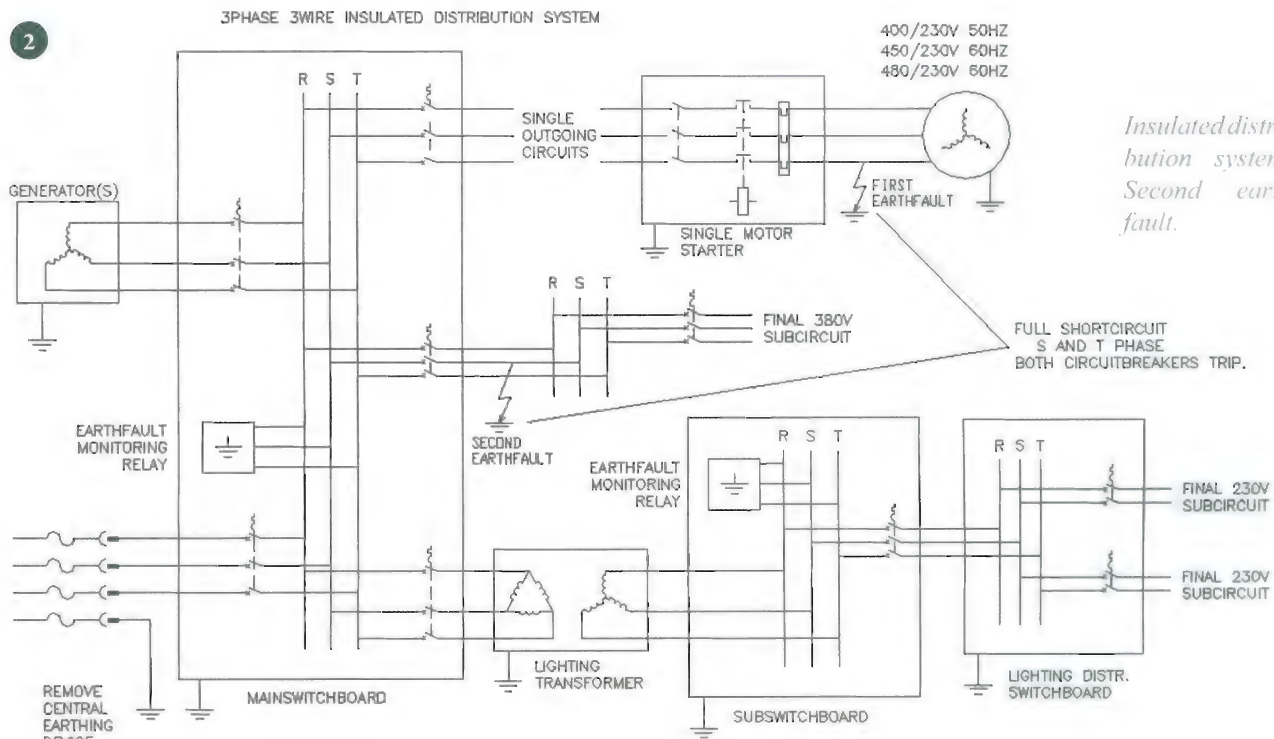
1. Bridge wing console
2. S-band radar.
3. AIS antenne
4. NUC lights
5. Magnetic compass
6. Wistle
7. Satcom antenne
8. X-band radar.

3 Insulated and earthed distribution systems

The early (3-phase rotating Alternating Current) electrical installations on board of ships were small, the cables of relatively low quality, and duplication of components or systems rare. To be able to continue operation with a single earth fault, the systems were insulated, i.e. no connection of the neutral (star point or zero) with the ships hull (earth). This made it possible to continue operation of the ship, in case of a single earth fault (1), while searching for this earth fault. A second earth fault (2) in a different phase would lead to a short circuit and tripping of both circuits.



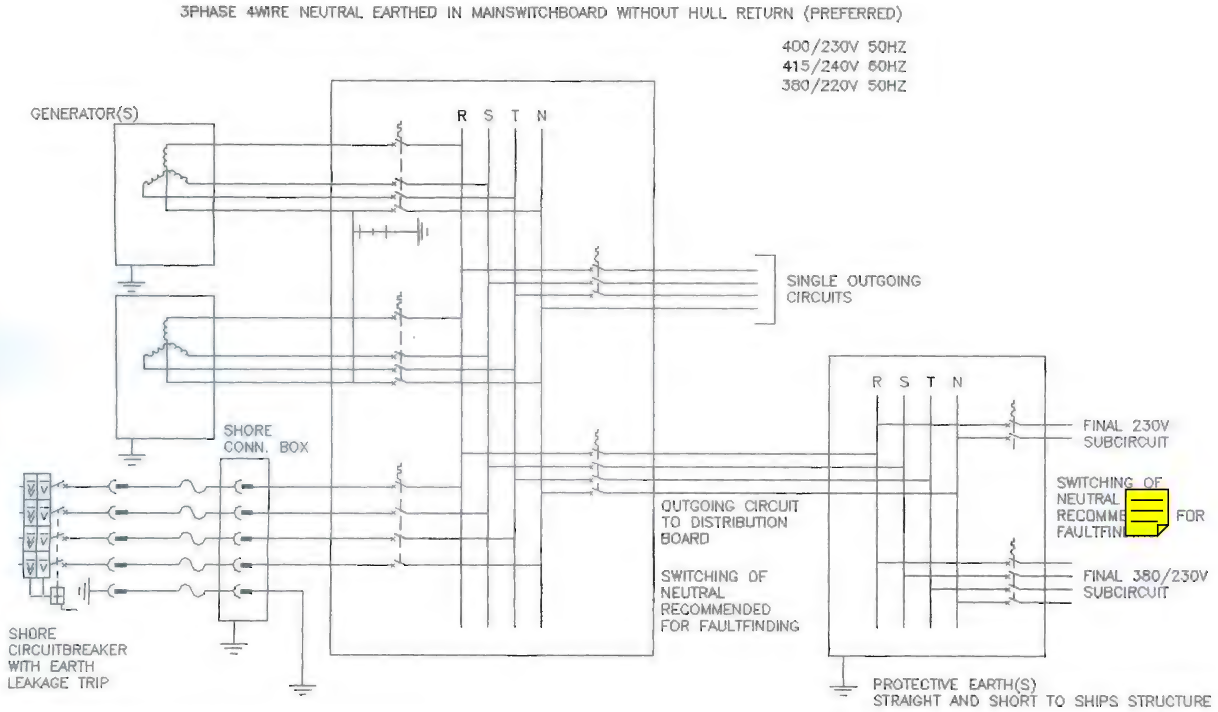
Insulated distribution system. A single earth fault gives alarm only in theory.



Insulated distribution system. Second earth fault.

Nowadays the installations and the capacitive coupling of the cable network to earth are large. Consequently, the current resulting from the first single earth fault, can be something like five Amperes, equivalent to a heater of five kilowatts at a location you do not know.

HE ABOVE AS ALTERNATIVES TO THE TRANDITIONAL INSULATED DISTRIBUTIONSYSTEMS AS KETCHED BELOW.



Earthed System Every earth fault is disconnected

In shore systems, the star point is always earthed, and the first earth fault results in switching off of the concerned faulty distribution group.
Based on the above, it is therefore recommended to use a 3-phase, 4 wire neutral earthed distribution system onboard ships, the same as used ashore.

Electrical equipment for ships in the past was specially designed for marine use, i.e. heavier insulation and more robust construction, but nowadays it is shore equipment which has been a litle adapted to the marine environment. The marine environment means: vibration, regular and irregular movements, of ships,working under angles, moisture, salt, dust etc different to most shore conditions.

Short circuit capability is the switching capacity of the circuit breakers and thermal strength of the switchboard. It is the maximum power the switchboard can handle without lasting damage. Damage can occur by the temperature rise from the short circuit currents as well as due to the forces occurring during a short circuit. When conductors touch each other due to the short circuit forces a second short circuit is developed in the switchboards. Also melting of insulation materials due to the heat can cause a new short circuit.

4 Basic design criteria.

The main criteria for the design of a ships installation are:

- Service, the expected location of the service of the ship, as you can see at 4.1
- Operation: the type of operation by the crew, in the engine room and on the bridge as you can see under 4.2
- Redundancy criteria, single or in some applications a second mechanical or electric failure, as you can see at 4.3.
- Maintenance, shore based or self-supporting, as you can see at 4.4.

The basic design as a result of above criteria shall be submitted for approval by a Classification Society and will consist of:

- Load Balance
- Short-Circuit Calculations
- One –Line-Diagram
- Selectivity Diagram
- Lay-out drawings
- Operational Description

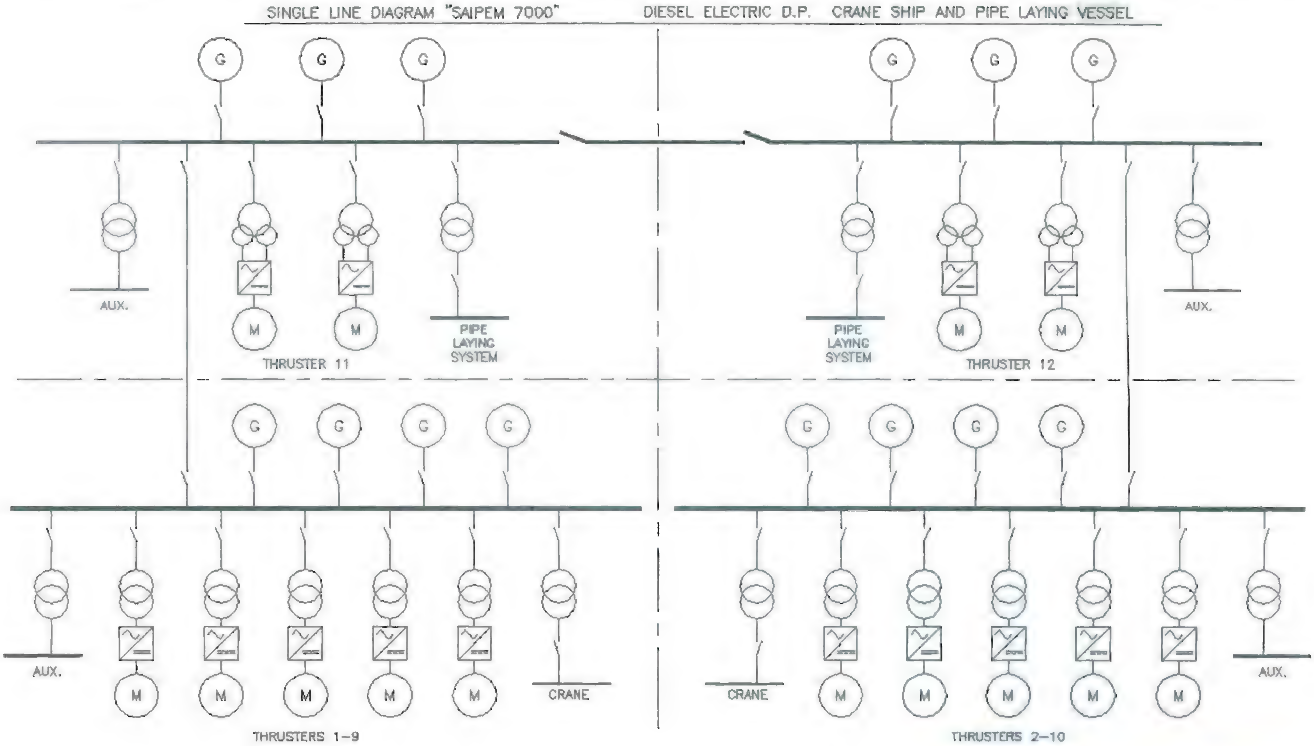
Also the requested Class Notation the code on the Certificate of Class is related to the design criteria.

The Load Balance is an analysis to establish the maximum needed electric power at any time, taking into account the power needed during all kinds of operation, under normal and in emergency conditions.
This means loading and discharging cargo, normal sailing, manoeuvering, at anchor, extremely high or low outside temperatures, extreme water temperatures etc. Emergency conditions, determing the rating of the emergency generator, vary from one type of ship to another.

Different kinds of ships have their own typical criteria: a normal cargo ship has different operational circumstances than a passenger ship, yacht, tugboat, dredger, offshore unit, crane barge etc.
Depending on the analysis, the number and rating of generators is decided. Also the energy need at several locations on a ship is calculated, determing the capacity of the cables feeding that location. Transformers are also dimensioned in this way.

One line diagrams shows the principal lay out of the electric arrangement of main bus bars. They also show separation and the division over bus bars sections of the essential consumers, and power supply to distribution boxes and panels throughout the ship.

Selectivity is a system of settings of electrical safety devices with the purpose to isolate the faulty group or circuit as close as possible near the fault. This to maintain power at as many other groups as possible. This requires fast and expensive circuit breakers. When some sub switchboards and a sequence of breakers are used, the solution can be very complicated and expensive.



ONE LINE SAIPEM 7000 a semi submersible self propelled Semi submercible Crane vessel also suitable to lay pipelines in a J-lay configuration

A good and clear one line diagram tells more about the electric installation of a ship than many pages of specification.

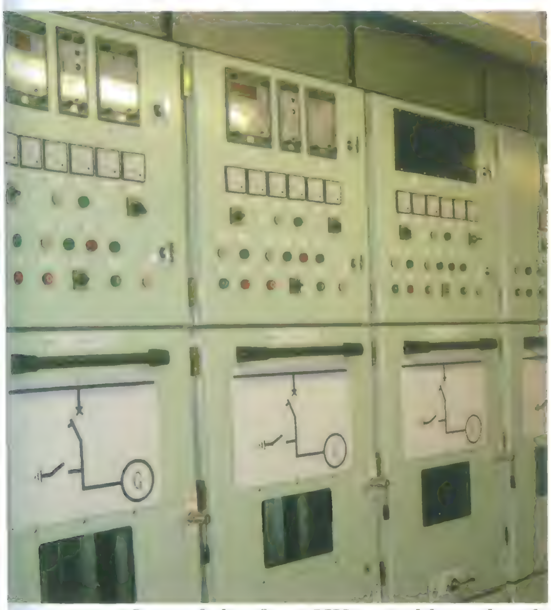
Semi Submersible Crane Vessel during annual DP trials near Malta

Often selectivity is only made in parts of a system, and to a limited current (partial selectivity).
When the current in the sub switchboard is higher, also the breaker in the main switchboard opens. Together the breakers can cope with the maximal current but the supply breaker to the subswitchboard has to be closed manually. This makes it necessary that essential duplicated users, being each other's redundancy, have to be supplied from different sub switchboards.

Lay out drawings indicate the locations of the main electrical equipment on a ship, and the main cable routings. Especially on ships with electrical propulsion and/or DP in combination with redundancy requirements the cable routing is important.

Functional description and detail scheme's are self- explanatory. They have to clarify the decisions regarding:
- Parallel running
- Synchronizing possibilities
- Instrumentation

They also have to include a description of standby and automatic starting functions of generators, automatic restart of essential users and all other functions to ensure power supply, coupled to manned or unmanned operation.



One of the four HV switchboards of SSCV SAIPEM 7000

The description of the functionality is looked at by the Classification and by the National Authority (Flag state). Sometimes the Flag state is leaving this to the Classification Society, which checks the design to its own Rules and Regulations and SOLAS, but also to the laws of the Flag state.

Engine control room

A selectivity diagram is a graphic display of the currents and time characteristics of circuitbreakers connected after each other. The margin in current and time between circuitbreakers after each other creates selectivity.

4.1 Type of Service

4.1.1 Inland Navigation

Ships that only navigate in rivers, canals, harbors etc. have a restricted area of operation. Help from shore in case of fire, or tugboats are available at short notice. Even those inland waterway ships that sail over the rivers and canals from Rotterdam to the Black Sea can expect help at reasonably short notice. This allows relaxation in the requirements for fire pumps, emergency batteries, and fuel tank capacity, compared with ships for less restricted service. This also applies for the requirements for communication equipment. There are separate Classification rules and regulations for Inland Navigation. For dangerous cargoes there are special regulations (ADNR) similar to the SOLAS Rules for sea going ships. Tank ships navigating the river Rhine are for instance required to be equipped with a back up propulsion system, giving the ships an emergency speed of about 3 knots.

A number of basically inland ships are adapted for Restricted Coastal Trade, for instance Rotterdam- Antwerp over the North Sea. And apart from the emphasis on closing appliances these ships also have to fulfill the SOLAS and COLREG requirements for coastal trade. Navigation lights according to the rules for sea going ships can be in conflict with electricity in dangerous zones (SOLAS are the IMO rules about Safety Of Life At Sea and COLREG are the Rules of the Road that is the Regulations to prevent collisions at sea)

Cargo vessel for inland waterways, with two push-barges coupled

4.1.2 Coastal Service

Ships that navigate in port or close to shore also have a restricted area of operation. In this case, however, at sea. They are obliged to navigate within reach of coastal radio stations and also within reach of service organizations, such as the coast guard. Communication Equipment has to be installed for Zone A1, and sometimes, when they are capable to do short sea crossings, for Zone A2. A1 is within reach of coastal radio stations and within reach of the coastguard. It allows lower requirements for emergency battery, emergency generator, fuel tanks and external communication.

Coastal diesel electric ferry

Mega-yacht, unrestricted service

4.1.3 Unrestricted Service

Ships navigating deep sea where, where no shore assistance is available, have to fulfill maximum requirements of SOLAS for battery capacity, fuel tank capacity, safety appliances, life saving appliances and communication equipment. Communication equipment in accordance with Zone A3, which means worldwide within the latitudes of 70° North and 70° South.

See for more details 8.2 External communication requirements.

4.2 Operation/ Engine Control

Engine rooms of modern ships are normally not "manned". The "unmanned" engine room is the normal situation. Unmanned means that whole engine room equipment can operate without attendance, controlled by electronic systems. Manual action is only required in case of a malfunction, indicated by an alarm for the engineer on duty who can be in his cabin or in the mess /recreation room

Only in day time the crew is in the engine room for maintenance and repairs. The Class notation for such an engine room is UMS or Unattended Machinery Space. A manned engine room, which means that 24 hours per day people are on watch looking at the running systems and adjusting when necessary, requires more people, with the obvious financial consequences. The availability of such crew is another factor. The engine room is a noisy, hot and humid environment. Modern automation and control systems allow the engine equipment to be monitored and controlled from a control room at least during a part of the time.

All systems must be so designed and installed, that under normal operational conditions, during normal sailing and maneuvering, no intervention of an engineer is required. During the sea trials at the end of the building period, it is a requirement that 4 to 6 hours of operation under varying circumstances can be completed without alarms and or shutdowns.

Engine control room from yacht with notation UMS

In small ships, or in countries where crew is relatively cheap, it can be worthwile not to install this sophisticated and expensive equipment but to choose for a manned engine room.

For some kinds of ships, for instance passenger ships, an unmanned engine room is not allowed.

Unmanned engine room require for example:

- Fire detection system
  Automatic protection by safety stops of main and auxiliary equipment, such as diesels, gas turbine, steam turbine, intended for propulsion or energy supply
  Remote control of propulsion and steering gear, from the bridge (bridge control)
- Automatic Starting/ stopping of air compressors and other equipment which is not running continuously.

Electric power generation systems are made automatic and self restoring sothat a second (standby) generator starts and comes on the net when the demand for electricity rises above a critical value. Also when a running generator fails a second set starts comes on the net and the electric powered systems restore automatic.

The essential elctric powered systems need to restart automatically and in sequence of importance: steering gear, lubrication oil system, high temperature cooling water, low temperature cooling water, saltwater, ventilation etc. Systems are self restoring: a second lubricating oil pump starts automatically when the pressure drops below a set value. A standby pump starts when the running pump fails

Automatic start of an auxiliary generator and automatic re-start of all essential consumers in case of a black out (failure of the running generator) is a SOLAS requirement for all ships where the steering and/or propulsion is dependent of electricity, even on ships with a manned engine room.

When the load requires parallel operation of two or more generators a non essential tripping system shall switch of the non essential consumers in case of failure of one of the parallel running generators. The power of this non essential trip shall be at least equal to the power of one generator.

This is to reduce the load on the remaining generator(s) to continue running, and to create time to start (and get on line) a standby generator.

Automatic control systems for the energy supply are called "Power Management Systems" (PMS). They start generators when the required power exceeds a pre set load per generator, arrange for synchronizing and load sharing. Also, when the load per generator becomes less than the preset value, they arrange for the contrary: reduction of load of a generator, taking the generator off line, arranging for a period running on zero loads for cooling purposes and afterwards stopping of the diesel.

In case only one person is in the engine room, that person needs to be protected by a "dead-man" system. When a person enters the engine room, he has to push a button at the entrance, which activates an alarm system, allowing him to be a limited time in the engine room. The system gives a pre-alarm after a set time (max. 27 minutes). When the person in the engine room does not answer that pre alarm within 3 minutes, the general engineers alarm is activated.

The alarm system is automatically deactivated in the unmanned situation. Normaly the dead man system is activated by a start button at the engineroom entrance. But if this has been forgotten every action in the control room, like accepting an alarm, pushing a start or stop button activates the dead man system. When the dead-man system is already activated it resets the safety timer to zero to allow him again the 27 minutes.

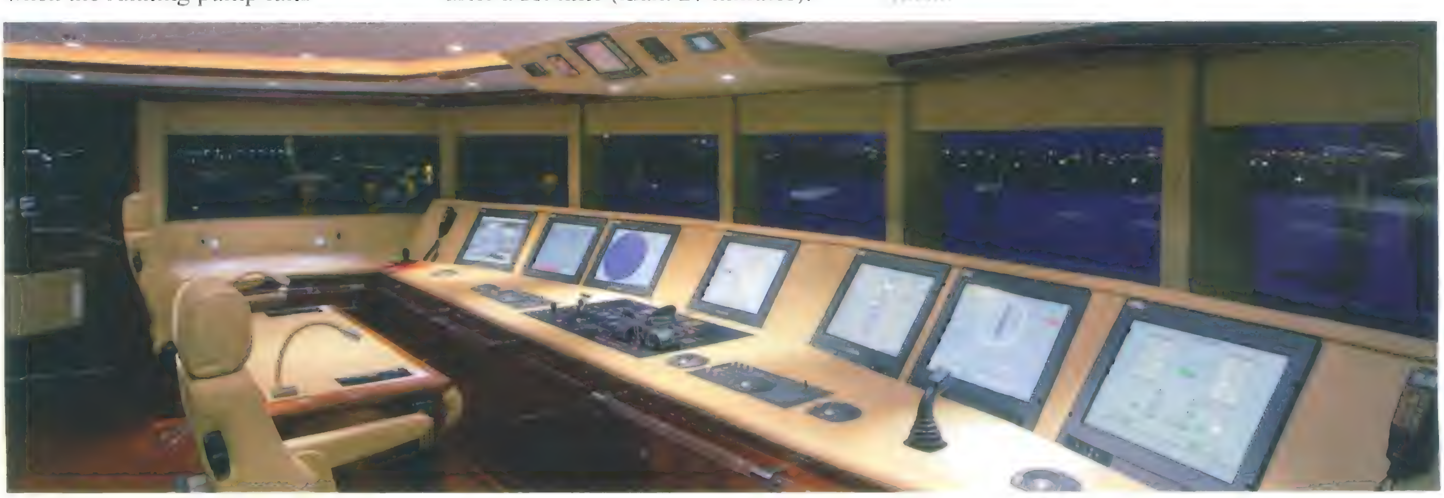
Resetting of the timer is also possible at various other locations in the engine room. The system has to be deactivated when leaving the engine room and remains standby for a next entry. Switching off, may only be done by the Chief Engineer, with a special key, and is only allowed when more people are in the engine room.

Requirements for the Engine room can be found in SOLAS.

The Integrated Bridge or One man on the Bridge (Notation IBS and NAV-1) is a further development of the bridge automation as the automatic steering control and control of the propulsion. Now also a number of nautical functions have made automatic. The integrated bridge, the next step, has the paper charts replaced by electronic charts on computer displays. The ships position is indicated on the display.

Even not certified as an NAV1 or IBS bridge the installation below includes a lot of the requirements.

Bridge console lay out motor Mega yacht.



One man on the bridge also requires the dead man's alarm system. It is already common in inland navigation and railways, and also coming into use on sea going ships. The minimal requirement is some kind of an audible alarm, with a maximal time span of 11 minutes. If there is no response within one minute afterwards, the other nautical offers will be alerted. An advanced timer will reset itself when any (electronic) action is carried out, similar to the engine room system.
Further requirements are: Two radars, one with ARPA (Automatic Radar Plotting Device) which detects other vessels at a course resulting in a dangerous situation, a collision, or just approaching too close. Range of the system and vicinity limit of a close coming ship are adjustable. Echo sounder with shallow dept alarm, independent off course alarm.
See further 9.
A number of Flag states do not agree with the One-man-on-the Bridge idea. For a passenger ship, the idea is not even under discussion. However, there is no doubt that periodical navigation by one man only on the navigation bridge will be the future standard.

Further required equipment:
Automatic Identification Systems (AIS) a signal, transmitted continuously by all the ships above 300 GT, in the VHF frequency, giving information about the ship:

- Name
- Identification number
- MMSI number
- Tonnage
- Cargo
- Destination
- Course and speed

This signal is received and displayed on the radar screen, showing all ships in the vicinity as an arrow and giving details of the particular ship when pointed at with the cursor.

Navigation lighting panel with alarm/ indication in case of defective light.

The integrated bridge is equipped with many screens on which various systems can be made visible. Not only navigation related with a DGPS position of the vessel on screen, but also other screens such as the radar, AIS, machinery status, propeller RPM etc. Separate workstations can be used for voyage planning. However, when one of the systems is malfunctioning, the screens go back to their main function, with minimal one radar, one control display and one alarm panel. This requires also more equipment: a second gyro and a second DGPS.

Ships where keeping or reaching a certain position has real priority (with DP Notation), such as diving support ships, pipe laying vessels, cable layers, drill ships, crane vessels etc. have to be equipped with even more back ups: three gyros, a double vertical reference unit, double wind measurement, double position sensors etc. (As you can see in Chapter 7, Dynamic Positioning).

4.3 Redundancy

Redundancy is the quantity of spare parts and/or systems which have to be on board/ installed to be able to continue the operation in case of a failure. Redundancy is for instance a second light in a space on another electric supply, the second power supply to the steering gear, a second generator connected to another part of the switchboard; a second pump automatically starting when first pumps stops.

Some types of ships have this redundancy not only in case of single failure of a pump or generator, but also in case of the break down of a complete engine room, by for instance fire or a flooding. The heaviest form of redundancy means complete duplication of engine rooms, including generators, switchboards etc. Redundancy is also applied in cable routing. The cable for power, but also for control of essential equipment shall not be on the same cable tray as the cables of the other identical equipment.
Redundancy is analyzed with a Failure Mode and Effect Analysis (FMEA). This is a listing of the possible defects and an analysis of their effects. It is not limited to electric components and systems only, but fuel systems, cooling water, starting air etc. are also part of the FMEA.

Redundancy is categorized in classes:
- Class 1: One single failure shall not stop the operation of the ship. This is on normal ships the usual criteria. Computer systems maybe single, but manual operation has to be possible.
- Class 2: more stringent, and requires two switchboards, and in case of computerized operation, there should be duplication by two computers, where each of the systems can operate automatically.
- Class 3: operation has to be maintained even in case of loss of a vital space as an engine room a switchboard room and a thruster room. This also means a second navigation bridge with the second computer control system.

The second switchboard shall not be installed in the same room as the first: Thrusters shall be divided over different spaces. Cables to the thrusters from the first and second control system shall be routed over different trays.

The way of control of an installation has its impact on the design: a manned engine room needs less control equipment than an engine room which is equipped for unmanned service. The NAV-1 notation implies more equipment, and also more redundancy of the wheelhouse equipment.

All the above considerations have their consequences for the basic design, including the location of the main equipment, the spare equipment and cable routing from for instance from main and back up controls to the thrusters.

4.4 Maintenance

Maintenance of the electric equipment can only for certain parts be carried out during an operational period. Duplicated equipment can be dealt with, as far as the redundancy is not coming into danger. Much maintenance has to be done by specialists, and has therefore to be carried out in port, where the specialist is available (and spare parts). Switchboards, circuit breaker and generators have to be left to specialists.

Maintenance on board is normally done with a planned maintenance system as directive. The required preventive maintenance is spread over the operational period.

AC Generator under maintenance

5 Electro magnetic compatibility

The shortest definition of EMC for English orientated people or EMV for Germans is:

> EMC is the capability neither to interfere with the (electrical and electromagnetic) environment nor to be interfered by this environment.

This is a requirement for all electric and electronic equipment on a ship. Interference can be the result of radiation or magnetic disturbance between cables as well as conducted interference via the power supply circuits

For navigation and nautical equipment an IEC (International Electrical Committee) standard IEC 600945 exists, controlling incoming and outgoing radiation and magnetic fields. All new and approved nautical and navigation equipment has been tested in accordance to this standard and can be installed safely.

It has to be clear that the equipment has to be tested in its original casings, using the prescribed cables, earth connections etc and needs to be installed on board in the same casings, mountings, earth connections, using the appropriate cables etc. Also earth connections are to be followed as specified. Also not navigation and nautical equipment that is installed in the wheelhouse has for radiation and disturbance to fulfill the requirements of IEC 600945. An EMC study results in an EMC plan, specifying measures and also a test matrix for the various systems.

Between the criteria safety margins are provided. Equipment which has been approved by the IEC Standard 600945, produces fewer disturbances than in the standard, and is able to operate without any problems within the defined environment.

A study of EMC is complicated and very time consuming. Installation of equipment which has been tested (and is proven acceptable) on EMC reduces the necessary effort considerably.

Radar antenna's shall be positioned to avoid blind arcs. Especially similar blind arcs for duplicated radars shall be avoided.

An EMC study starts with making a list of the transmitting and receiving aerials in sequence of their priority including their installation requirements and starting with positioning number one of the list at the best possible position. Hereafter number two on the list is positioned and so on. This defines the technical topside arrangement of ships antennae.

Radiation test at an EMC laboratory

Immunity test at an EMC laboratory

Disturbing fields are caused by radiation and by signals through insufficient (for certain frequencies) shielded cables. Much of the used equipment is tested and type approved. Testing is done to measure if magnetic fields and signals from cables are disturbing the proper working of the tested equipment. Also, if the equipment itself sends out unacceptable fields and signals. Grouping and separation of cables, in relation to the type, frequency, strength of the signal they transport and is essential to realize a good working installation.

When interference is too high, it has to be reduced by relocation by shielding of the equipment, by screening or for instance re-routing of cables.

The quality of the power supply systems is also part of EMC. The tolerances in Voltage (AC and DC) and in case of AC also in frequency and tolerance in wave-form i.e. deviation from the sinus-curve, are maximized. The ideal Voltage curve with the lowest heat losses is the mathematically correct sinus curve. Theoretically this can be produced by a perfect generator, but in practice this is always a compromise. All electrical equipment has to perform without problems when getting power with a maximal total harmonic disturbance of 5%. This means that the area difference between the actual signal is less than 5% with the mathematically correct sinus.

In case much of the consumers consists of "frequency controlled drives" as in electrical propulsion with fixed pitch propellers and a variable rpm, it can be simpler and cheaper to design at least a part of the equipment that it accepts a larger total harmonic distortion figure. For an electric propulsion system with large generators, large frequency convertors and large propulsion motors the design can be made that the system operated satisfactory with a larger THD. Also the switchboards with the electronic protection devices shall be suitable for this THD. Sometimes string-tests are needed to demonstrate this. A string-test consists of a generator, a representative part of the switchboard, a transformer a frequency convertor and an electric motor under load. This is an expensive and time-consuming test. It is better to make an EMC plan, to estimate the expected disturbance of the sinus, and only to order and install equipment which can cope with the expected disturbance.
Equipment can then be tested individually, and later installed into a system. Filtering to the 5% THD limits is than done only for a limitted power to supply the standard equipment. In that case only that part of the installation has to fulfill the IEC-Standard 60092-101 stating figures for power supply systems.

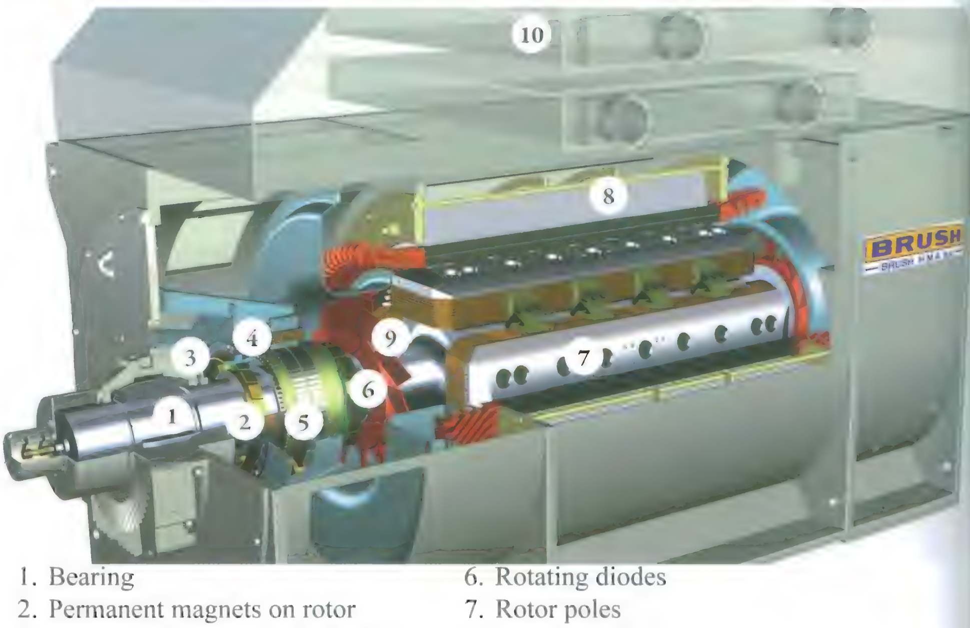
6. Main components

6.1 Generators

A generator is a relatively simple device, transforming mechanical energy into electric energy. In most ships the mechanical energy for the generator comes from diesel engines. Some LNG and LPG tankers have a steam propulsion plant and also turbine generators. The main objective is to produce AC for electric motors.

Revolution per Minute (RPM) of motors (and generators) is related to the 50 or 60 Hz current supplied by the generators.For generators and for motors the relation quantity of poles, frequency and RPM are the same. See electric motors 6.2.
The higher RPM figures as 3600 RPM are used in small generators (portable) and in large steam or gas-turbine generators. For the explanation of the working of a generator see 1.2 Alternating Current (A.C)
More power usually means a lower RPM: 1000 kW comes normally from a generator with 1800 RPM, 6000 kW if driven by a diesel engine means 720 RPM.
Power Take Off (PTO) generators get their power sometimes direct from the propulsion engine, usually via a separate gearbox to a suitable speed of 1500-1800 RPM. The propulsion motor is usually a medium or high speed diesel. When two diesels together drive one propulsion shaft, there is one gearbox, with internally one or two drives for a PTO. Remote controlled friction couplings allow the running or nor running of a generator.

A PTO generator is normally rated to take the full electrical load during normal sailing of the ship. The auxiliary diesel generators then can, during the voyage, be left unused. They are started and put on line during maneuvering and also in harbour when the main engines are not in use.
Also large ships, with slow-running cross head engines, directly reversible, sometimes are equipped with a PTO. The low RPM of this type of engines makes it difficult. A 60Hz generator with RPM between 100 and 120 is a very large machine. This problem has in some cases been dealt with by using a planetary step up gearbox, with the possibility to convert the main engine input RPM, which can vary, into a constant output RPM, and so using a generator running at 900 RPM developing about 1000kW.
Electric power from a PTO generator reduces the running hours of auxiliary engines and is also fuel wise cheaper. Most main engines are running on heavier fuel than auxiliary engines and heavier fuel is less expensive. Also the cost of replacement parts is saved.



1. Bearing
2. Permanent magnets on rotor
3. Permanent magnet coil on stator
4. Stator exciter winding
5. Rotor exciter winding
6. Rotating diodes
7. Rotor poles
8. Stator windings
9. Fan
10. Heat exchanger water/air

Environmental condition	Example location	Type of protection	Permitted equipment		
			Switchgear	Machines	Lighting
danger of explosion	tankerdeck	explosion proof	yes	yes	yes
	hold for dangerous goods	intrinsically safe	yes	not possible	not possible
	paintstore see 10	explosion proof	no	no	yes
	battery rooms	intrinsically safe	no	no	yes
	cardecks[1]	intrinsically safe IP55	yes	yes	yes
danger to people	dry spaces	IP20	yes	yes	yes
	cabins	IP20	yes	yes	yes
	corridors	IP20	yes	yes	yes
dripping water or light mechanical damage	engine controlroom	IP23	yes	yes	yes
	navigation bridge	IP23	yes	yes	yes
	enginerooms above tweendeck	IP23	yes	yes	yes
splashwater or moderate mechanical damage	enginerooms	IP44	no	yes	yes
	bathrooms	IP44	no	yes	yes
	galley	IP44	no	yes	yes
	laundry	IP44	no	yes	yes
spraywater or dust	enginerooms below floorpates	IP55	no	yes	yes
solid water	foreship	IP67	no	yes	yes
	opendeck	IP67	no	yes	yes
underwater[2]		IP68	no	yes	yes

1 45 cm above floor
2 figure stating max depth

This summary is not only applicable to rotating equipment but also to switchgear, illumination equipment socket outlets etc

6.2 Electric Motors

Electric motors transform rotating Alternating Current into rotating mechanical energy. How they work is described under AC. The three phase electromagnet is the (non rotating) stator, and the short circuited cage, the rotor. The cage is built up from two copper rings, connected by a number of copper rods, short circuited, a bit under an angle with the shaft. The current in the stator creates current in the rotor which results in a magnetic field.
The stator creates magnetic fields in the cage which want to follow the rotating magnetic field in the stator. It does so by rotating. The table gives the theoretical revolutions per minute (RPM) of synchronous electro motor and synchronous generators in relation to the main power frequency and the quantity of poles:

3000/3600	RPM	2-poles 50/60 Hz
1500/1800		4-poles
1000/1200		6-poles
0750/0900		8-poles
0600/0720		10-poles
0500/0600		12-poles

Depending on motor power the actual RPM of asynchronous motors is 2-5% lower due to slip

From the table can be concluded that a rotary convertor (AC generator 60Hz driven by an electric motor) from 50 Hz can be done without gearbox or V-belts at 600 RPM, 10 phases on the motor and 12 phases on the dynamo, on one shaft. Rotating Alternating Current motors have, in relation to RPM, the same possibilities and restrictions as generators.

The energy used by the rotor of a squirrel cage motor to become magnet, is developed by the slip. The slip is the difference between the RPM of the rotating field and the RPM of the motor.
When the rotor gets its power to become a magnet from an external source, there is no slip. These types of motor are called synchronous motors. The cage is here replaced by a rotor with windings, and the electric power comes in the rotor through brushes on sliprings

Motors with a permanent magnet as a rotor do not have a slip either. Starting is a problem, for they cannot follow the stator field instantly, and need to get started through a frequency convertor, from zero RPM at a low Voltage to full RPM at the generator frequency and full Voltage.

Motors are on the market in various standard dimensions, with respect of height and diameter of shaft (and key) and foundation. Ball bearings are also standardized. Motors are made for vertical or horizontal position. For vertical position with a flange and for horizontal installation with feet. There is a difference between DIN (German standard) and JIS (Japanese standard) in foundation dimensions because of location of feet.
Electric motors are supplied in various protection classes: from protection against moisture, up to submerged conditions, and for use in dangerous zones up to explosion proof.
The International Electrical Committee (IEC) has issued the standard 600529, with protection classes for electric equipment as follows:
- IP 23 is the minimal protection class for engine rooms,
- IP 44 for engine rooms at floor plate level
- IP 55 for enginerooms below floor plates as well as partly suitable for dangerous areas
  IP 68 for motors outdoors, for locations where submerging is possible, such as on the forecastle and maindeck. Depending on the possible water pressure additional specifications are made.

Hih voltage cables

Additional fire protection around cables

Cable and pipe tunnel on a heavy cargo vessel

6.3 Cables

Cables are the connections between the various components of the electrical installation.
The cable system is, due to do the high quantity of man hours involved in pulling cables, fixing same on cable trays, making the connections to the equipment, and the testing, the largest cost factor in a ships electrical installation.

Cables are not calculated to be capable of transporting the energy to all users together at the same time. Not all equipment is supposed to work at the same time. Also generators are not supposed to supply all equipment together at full load at the same time.

Cables are made in a lot of different types: Cheap PVC, XLPE, low smoke, low toxic and fire resistant al depending on the properties of the materials used.

The cheapest cables are those insulated with PVC. They are limited in use; up to a maximum conductor temperature of 60 °C and these types of cables are dangerous in case of fire. Fire in an installation with cables insulated with PVC produces black smoke and corrosive and toxic gases not only in the area where the fire is, but also far around.
More expensive is a cable with XLPE insulation. The maximal working temperature of this material is 85 ∘ C, which allows an approximately 25 % higher load. These cables are free of halogens and produce no toxic gases under fire conditions.

Further types as Low smoke means that in case of fire the cable produces hardly smoke and soot.
Also Low toxic cables produce low quantities of aggressive chlorides. This reduces consequential damages in case of a local fire.
Fire Resistant Cables, or cables with function retention, have a wrap of mica around the conductors, keeping them in service up to 1000°C for at least one hour, in accordance with the SOLAS A-60 requirements.
This type of cable has to be used for systems which must keep their function in case of fire, such as alarm systems, emergency lighting systems, public address systems, control systems for fire fighting, emergency stops etc.

Also cables passing though one zone, for alarms or essential services in the next zone have to be this type of cable. Proper routing is also important. For instance power cables for fire pumps routes through a space the pump is supposed to protect have to be a fire resistant type. The same is applicable for control cables for the same pumps.

6.4 Switchboards and other combinations of switch and control gear

Switchboards, sub switchboards, section boards and other panels with switches are needed to connect and disconnect users from the main distribution system, or from the generators. The legislation for operators shore installations in most countries is clear with respect to equipment and protective measures necessary to safely shut down an electrical installation (or a part thereof and how this installation can be made live again safely is defined in laws)
Also the knowledge and certification of the operators is laid down officially.
For ships this is still under development. European and global standardization committees are working on it. A proposal for the safe operation of a ships switchboard is at present (2007) being reviewed by the IEC (International Electrical Committee).

Switchboards are provided with circuit breakers and protection relays of generators, cables bus bars and circuitbreakers to supply users. Switchboards are used and operated by ships officers, but service and repairs have to be left to specialists.

Switchboard distribute the electrical current, and protect the generators, the cables, switchboards and sub switchboards against damage from too high a Voltage and too high a current or even short circuit currents.

Synchronising panel

1. Voltmeter busbar
2. Voltmeter incoming machine
3. Synchronoscope,
4. Frequency meter busbar
5. Frequency meter incoming machine
6. Control pushbuttons circuit breaker
7. selector switch incoming machine

Generator panel

1. Ammeters R- phase
2. Ammeters S phase
3. Ammeters T phase
4. Voltmeter generator with phase selector switch
5. kW meter
6. Frequency meter generator
7. Indication lights circuit breaker open, tripped, closed etc
8. Breaker manual control pushbuttons
9. Off, running standby selector swich
10. Stand still heater switch and light
11. Stand by indication light

High Voltage switchboard

1. Aux. Generator panel
2. PTO. Generator panel
3. Bustie/ synchronizing panel
4. Bowthruster panel
5. Transformer panel to low voltage airconditioning distributions

One of the main differences between a shore switchboard and a ships switchboard is the level of protection against moisture and dust related to the location of the ship as well as the movements of a ship. Ships often make an unforeseen movement which necessitates protection against touching parts under Voltage, even during the simplest repair.

Doors have to be provided with locks, securing them in open position, to prevent a door closing by the movement of the ship hitting an engineer. Under the "simplest" repair comes the exchange of a fuse or the manual resetting of some control inside the switchboard.

All the panels which contain fuses circuit breakers and other equipment which has to be operated incidentally by the operator are to be protected against accidental touch of life parts (IP20). An insulated handrail at the front side of the switchboard to enable the operator to secure himself is another requirement. Panels which contain non screened life parts are to be locked for operators and can not be opened without tools

A ships switchboard is built up from independent vertical sections, at least one panel per generator, and two for the distribution groups. The vertical division between the sections is to prevent damage to the next panel in case of an arc (fire). The rails, or bus bars, have to be provided with removable sections or other devices to isolate sections of the switchboard for maintenance, repair or service.
When parallel mode is required a synchronizing panel is added, with two possibilities for synchronizing. A check synchronizing relay has to prevent switching in out of phase even in manual synchronising.

All essential and therefore duplicated users have to be distributed over the various sections such, that in case of loss of one part, operation is still possible via the other part. Propulsion and habitability have to be ensured. The international legislation is now adapted to the extent that accommodation ventilation and the galley ventilation may not be out of operation for a considerable time or permanently.

6.5 Circuit breakers and contactors (magnet operated switches)

A circuit breaker is designed to be opened and closed under nominal current conditions (Interruption of short circuit current is limited to a number of times without maintenance). This makes a circuit breaker unsuitable to switch on and off a large motor, as the staring current is 8 to 10 times the nominal current

Some manufactures specify an opening (breaking) capacity for one time only after the circuit breaker has to be replaced. In that case the circuit breaker is some kind of a fuse and spares shall be carried.

A contactor is designed to be closed and opened thousands of times for the high starting current of electric motors.
Closing (making) and opening (breaking) capacities are specified in relation to nominal voltage

Large contactor

Small Contactor

Large with drawable (5000 A) Circuit breaker with electronic protection unit

6.6. Type- Approval of Equipment

Type Approved Equipment is equipment that has been tested for its ability to perform properly in the marine environment, as described in the rules and regulation of the Classification Societies as well as IMO requirements

The marine environment is defined as follows:
- Environmental air temperature 45 ° C (other values for restricted service area possible)
  Sea water temperature 32 °C
  Relative humidity maximal 95 %, no condensation
- Trim (longitudinal heel) +/- 5% static, with movement +/- 5%
- Heel (transversal) +/- 22 ,5 ° with roll another +/- 22.5°
- Roll period 10 sec
  Vibration depending on location
  Impact (shock) depending on location.

In addition to the above criteria the following tests are also carried out:
- Disturbing other equipment by producing radiated or conducted interference
- Sensitivity for electro magnetic radiated or conducted disturbance from other equipment
- Sensitivity for variations in Voltage and frequency.
  Sensitivity for Voltage interruptions, especially for PLC and PC systems. Programs have to be restart safely.
- Measurement of harmonic distortion. Most of the industrial equipment has been designed for an AC Voltage with a total harmonic dissertation of 5 %. In case this distortion is larger; more heat is produced, which can cause defects.
- Working of the apparatus in general. Accuracy etc.

All essential equipment shall be chosen from lists of type approved equipment, as issued by all Classification Bureaus'. In case equipment is not listed it can be separately tested and cerrtified to be suitable for the single application.

6.7 Starting equipment

Starting equipment is used to reduce high starting currents of a user when this user is connected to the power supply system. The main objective is to prevent a Voltage dip in the power supply system to the extent that other users are not influenced. This is done for instance by using a star-delta starter, a starting transformer or a frequency transformer/converter (soft starter).
Starting equipment is also used to reduce the starting torque of an electric motor and herewith an excessive torque on the driven equipment. This is to prevent mechanical damage. Not rotating equipment, such as transformers sometimes needs starting equipment during building up of the magnetic field. Direct switching on results in large magnetizing currents which can trigger the safely functions of the transformer, and can cause a too high Voltage dip. Pre magnetizing resistances can be used, which after a certain time are by passed to solve this problem.


Small starter drawer


A emergency generator with emergency switchboard

6.8 Emergency Power Supply and Emergency Generator

On small ships, the power for emergency systems is usually supplied by batteries: for emergency lighting and communication, and for a limited period. On large ships and ships with 32 passengers or more the required time that the emergency systems have to be operational is too long, and the quantity of necessary batteries would be too much to be practicable. An emergency generator is then the solution.

An emergency generator is a generator with the same particulars as the main generator(s), as far as Voltage and frequency are concerned. This generator has to be installed in a separate space, independent of any equipment in other spaces. This means that the fuel tank, starting equipment, (batteries, start air receiver) the emergency switchboard and the emergency lighting switchboard and the emergency lighting switchboard are all together in one space. This to prevent the breakdown of the emergency power supply in case of fire in a nearby space and to continue the emergency supply as long as possible. The rating of the generator has to be based on the systems which have to be supplied.

An emergency generator has to be located above the freeboard deck and aft of the collision bulkhead. The cables, supplying the various emergency systems have to routed outside the space where the main generators and/or main switchboard are situated. An emergency generator has to be provided with a second starting system, capable to start the diesel independent from other systems. This may exist of second set of starting batteries, a hand starting diesel compressor to refill the starting air bottle in case of an air-starting emergency generator.

Other possibilities are hand operated hydraulic starters and spring starters. The emergency switchboard has to supply the emergency users, such as emergency lights, watertight doors, navigation lights, the emergency fire pump, steering gear, internal and external communication systems and the navigation equipment.

7. Control engineering

Control engineering is the complete scala of control and operating equipment, often programmed, used to make the control over a complete engine room easier, more comfortable and to be carried out by fewer people.

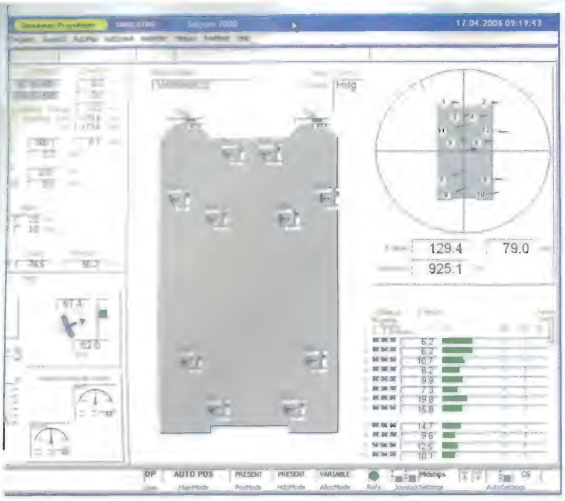
Control Engineering also allows the execution of the orders to equipment which is too complex to be operated manually. An example is a ship, which has to be kept in location using 8 azimuth thrusters. A joystick translates the requested force and direction into 8 different signals to the thrusters. Manually this would have been done by fixing six thrusters in the approximately wanted direction with an estimated required power and with two thrusters with varying power and direction manually, to do the necessary corrections. The automatic system can do this more effective and faster if properly designed, adjusted and tested

Control Engineering enables to observe and to register data in connection with the whole engine room, in normal operation, but also of alarms, defects etc. Also the necessity of rectification of defects, such as the changing of a filter when the pressure difference over the filter has been measured as being too high, or to change to a standby pump when a measured value requires that. Registration of running hours in combination with load is an indication for planned maintenance.

The scope of the control engineering installation is determined by following factors:
The owner's wishes
- The function, objective of the vessel
- The Cost
- The number of available crew
- The education of the crew
- The complexity of the installation
- Class, IMO, Flag state requirements

It has to be clear that first an analysis of cost versus. benefits has to be made in connection with the total extent of the control/engineering before the design and technical calculations are started.


Thruster Control console with 12 control handles of 12 individual thrusters



Thruster Control MIMIC

Integration of systems, introduction of distributed systems, location of input/output modules opposite to sensors, and the communication, via a two core "serial bus" are more often used, but are for the authorities difficult to judge whether the reliability requirements are met. When the input/output modules are fitted close to the sensors, many multi core cables to the control computers can be omitted.
Smart sensors similar to the addressable fire detection sensors may reduce the cable required in the future.

SCADA short for Supervisor Control and data acquisition system is software that collects and analyses real time data and presents this in a logical way. To give an example, the system detect a leak in a pipe, collects information about the function of the pipe, analyses the consequences and alarm engine room or bridge personal, takes corrective actions and advises how to proceed further.

A SCADA package that creates an operator friendly presentation and control at a PC type workstation makes operation and supervision of an installation less complicated. It reduces cost of crew and of the total installation. Processes are changing so fast that many well educated designers and operators are not able to keep track.

SCADA Mimic propulsion observation

Another problem is that the legislation of Class and Flag states is not able to keep pace with the development of the equipment. They need to understand that they cannot stand still at a certain technological level but have to be flexible in accepting progress in engineering. The legislation should only specify results.

Redundancy in equipment and in software is required. Software has to be developed in a structure and to consist of modules, which can be individually tested and approved. In the end the integrity of the whole system has to be tested. This also brings the advantage, that in case of modification of one module; only that module has to be re tested. Re testing of the whole installation is then prevented. Software, and alternations to software, has to be documented. Manual operation has to remain available, and has to be common knowledge, for all systems.

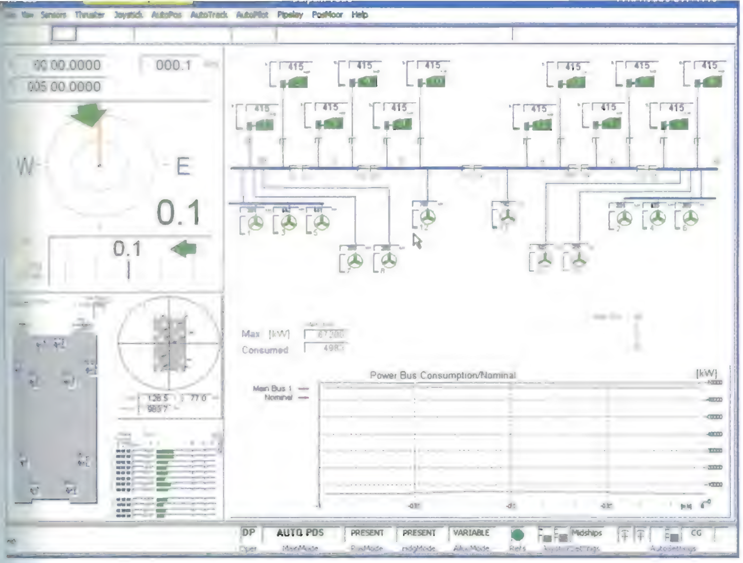
The common systems at present are:

- Engine room alarm and observation system, consisting of simple indications showing the status of alarms and analogue values of those alarms
- Inteligent workstations for alarms and observations, making complex systems visible, operator friendly by for instance touch screens, or internet related operation structures, leading the operator from one step to the next step in the system. Stored date can be transformed into a trend, relations between various systems can be made and defects predicted based on running hours.
- Tank gauging or level measurement, combined with temperature date (at various level) and with a given density, transferred into tank content in m3 and/or tons.
- Cooled container observations from a simple temperature alarm, up to temperature monitoring system, measuring also CO2 and other relevant date continuously and storing/writing those data.
- Generator control and power management systems of an automatically starting standby generator and re start of all essential users.
- Power demand related starting or stopping of generators and continuous load sharing over the running generators
- Propulsion remote control from one engine straight shaft fixed pitch propeller to a complex joystick control, dealing with thrust and power in every desired direction via a computer translated to a signal to each individual thruster.

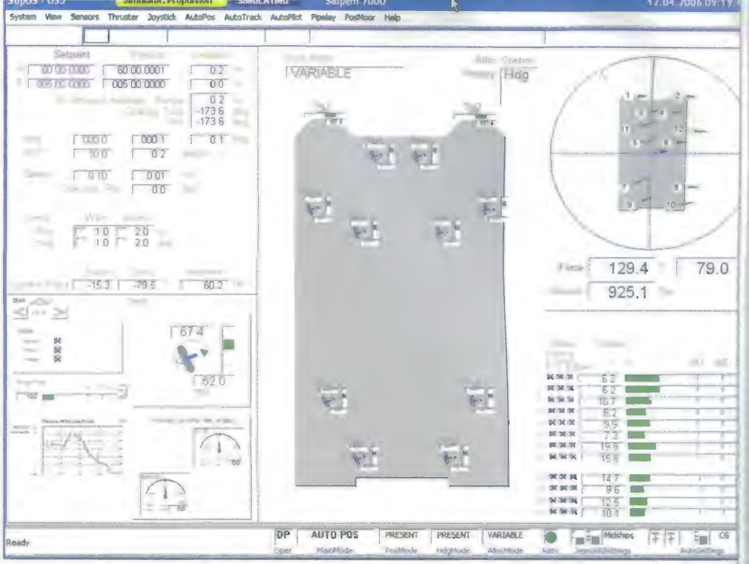
Everything that can be thought off how to manoeuver and control an installation is basically possible. Also the storage of data and the graphical display of same in different ways. Logbooks can be provided, which only have to be signed.

Dynamic Positioning or DP installations are state of the art control systems. With satellite position (GPS) indication and various ships sensors as input. These systems are able to keep a ship or platform at its location, or to steer along a prepared track, independent of the weather, current or other disturbing factors. Speed can be made dependent of parameters such as water depth or wave height. A command such as: '25 meters from the berth, afterwards rotate 180 ° clockwise, with the stern as centre of rotation is possible. There is no limit in possibilities the control engineering, but the yardstick is laid by cost and revenues.

The fast development of displays screens, presentation and control software packages, computers, programmable logic controllers, communication bus systems and intelligent data collection and control units makes the impossible possible. However, for each design one has to investigate how to remain in control manually when one or more modules of the system are out of order. It is therefore imperative to make Failure Mode and Effect Analyses (FMEA): an analysis which shows the effect of each possible defect. Such analysis should not be restricted to the electrical part of the installation but should also include the hardware, such as switchboards, generators, transformers, UPS, and also the non electric systems such as fuel, cooling water, starting air etc.



SCADA MIMIC DP control console Power



Thruster forces

This SCADA mimic gives the same information as at the Thruster control console with individual controls and indicators as well as the calculated results of all the thrusters together

7.1. Alarm Observation and Control Systems

The hardware for Alarm, Observation and Control Systems is available on the market in all kinds of range and possibilities. The simplest alarm system consists of a 10 channel unit for 10 digital alarms with a common outlet for a groups alarm and a claxon, with a stop horn button and a reset button. Alarm and observation systems are developed to observe automatically all important data of an installation, and to identify any deviation. Herewith time is gained during watch keeping, and values are checked more often and more accurate. It has to be clear that such systems never can replace a watch keeper making his round and noticing for instance a slowly growing leakage in a coupling or flange before the bilge level alarm goes.

The simplest system show an alarm with a flashing warning light, a nameplate and an audible signal by a claxon. When accepting this alarm by pushing the acceptance button, the claxon stops but the light remains lit. When the value changes out of the alarm setting, the light goes out. When only the "stop horn" is pushed in, the claxon stops, and the light remains lflashing, even if the value changes to the normal settings. When the sensor comes again in alarm, this will not sound the claxon again.

Depending on the notation 'manned engine room' respectively 'unmanned engine room' and the extent of the installation, larger systems are installed, often a combination of more de-central input/ output units, connected to each other by a redundant network, but still producing their alarms by a simple warning light and a claxon.

Groups alarms can be sent to the wheelhouse, indicating that it is advised to reduce speed or that an engine stop is imminent or is there already etc. The more sophisticated systems have a graphical display possibility at a screen of a workstation. Essential automatic systems have to be built up from type approved components, have to be tested in the workshop of the supplier, and have to be provided with a certificate.

7.2 Voyage Date Recorder (VDR)

To enable investigation into the cause of accidents or near misses, ships are similar to airplanes, equipped with Voyage Data Recorders. These 'black boxes' are bright orange floating recorders, and store the data of the last 24 hours. The stored data are from the main engine, the alarms and the navigation information. Also recorded are the radar pictures and the conversation in the wheelhouse. The VDR is usually placed on top of the wheelhouse, and floats up in case the ship sinks (or when released manually). When floated free or activated it transmits a beacon signal, in order to be found easily.

8 Communication systems

Communication systems are due to the decreasing number of people (crew) on board more and more important. In connection with this ongoing reduction in crew, portable communication equipment has been developed, which can be used for voice communication and for reading and accepting alarms. Also from the shore the status of the automation equipment can be followed which gives the possibility to give advice for corrections or repairs, if required. E-mail, data communication and world wide telephone contacts are normal practice.

Voyage Data Recorder

8.1 Internal Communication

Talk Back Systems. A loudspeaker also functions as a microphone. The control station is at the bridge, enabling two way communications with slave units. Slave units cannot communicate with each other. These slave units are installed on the fore castle, at the poop deck, in the engine room and in the steering gear room. This was in use during mooring and unmooring but lnow mostly replaced by handheld VHF.

Battery less Telephone System (Sound powered telephone system)
An old fashioned system, but still in use on many ships. Calling is done through a hand generator in combination with a location switch. Listening and speaking is in parallel. The system is in use for emergency communication between bridge, steering gear control room, engine control room, fire control room, emergency generator room etc. At present telephone systems are often UPS powered, which has ended installation of sound powered systems in new buildings.

Automatic telephone installations on board of ships are very much the same as ashore, however, the supply comes from a UPS unit, and in case it is also in use for emergency communication, they have to be provided with an interruption possibility from the emergency communication locations.

Paging System
This is a one way system between the Navigation Bridge and crew/passengers. The purpose is to inform large groups of people, and to call individuals. The systems can also be used to give general alarm, fire alarm, and for other messages to crew and passengers. The system and the cable network have to fulfill the SOLAS requirements for this kind of installation and cables such as duplicated amplifiers, divided circuit, fire resistant cables, to prevent that a single fault in the system or the cables, makes the whole system useless.

8.2 External Communication Systems

The required ship shore communication is related to the chosen operation area.

A1 is the area close to shore, within reach of the VHF Coastal stations
A2 is the next area in size, allows more distance from shore, and limited crossings, for instance the North Sea.
A3 is the worldwide, however, without the polar regions i.e. between 70 ° North and 70 ° South.
The A-3 area is covered by the satellites of the GMDSS System. Ships with the Notations 'Unrestricted Service' this basically means all ships which make long voyages, must fulfill the A3 requirements.

Global Maritime Distress and Safety Systems (GMDSS)
GMDSS are the abbreviations of the above system. It uses the communication satellites of Inmarsat. International Marine Satellite is a system supported by some 60 countries. These countries finance the system and collect the dues in proportion of the using. The system enables automatic communication and is provided with interruption possibilities in case of emergency and distress messages. Various communication standards are possible. The system is based on being used by the ships nautical officers, which means that no radio officers are needed on board. Therefore it is imperative that the maintenance and repairs is done by a shore based company, and that the equipment is duplicated. Inmarsat works with geo-stationary satellites, located at the equator, at a height of approx 36000 km.

A-4 are the Polar Regions. The Inmarsat satellites cover only the area between 70° North and 70° South. The Polar Regions, not covered by the satellites require a complete, old fashioned set of radio communication equipment operating independent from the satellites.

9. Navigation and nautical equipment.

Generally, the following equipment is installed:

- A Radar with ARPA (Automatic Radar Plotting Aid), this is an automatic collision warning installation, with a rotating transmitting/ receiving antenna, working in the X-band, 3 cm wavelength.
- A second Radar, for ships larger than 500 GT. Usually working on an different wavelength, as the two types of radars give different pictures of heavy rain showers, seaware reflections, fog etc working in S-band 10cm wavelength.
- Two independent position indicating systems, GPS or even more accurate: DGPS, with an omni directional satellite receiving antenna and a parabolic correction antenna.
- A water depth meter: echo sounder, with printer.
- A speed indicator with distance counter (log)
- A magnetic standard compass. A magnetic compass has to be calibrated; this means that is to be corrected for the influence of the ships (magnetic) steel. The deviation of the compass from the magnetic North direction has to be minimized. This in done by adding small magnets to the compass.
- A gyro compass
- An automatic pilot
- AIS automatic identification system

Modern bridges are equipped for watch keeping and sailing by one man (Notation NAV1). The view in all directions has to be (more or less) unobstructed from the operator's position, from the chart table/ route planning workstation and from the communication desk.

Alarm systems monitor the navigation lights and other nautical equipment such as radars, echo sounder, gyrocompass, automatic pilot etc. The ARPA function of the radar has also an alarm, in case a ship is calculated at a collision course or coming too close. The echo sounder has a depth alarm, audible, when the depth is becoming too shallow.

Conning section of wheelhouse console m.y "AMEVI" with main engine and steering controls autopilot as well as conning display compiling nautical data from other instruments

When the ship unintended changes direction, an off course alarm, independent from the gyro, has to give an audible warning.

A Watch keeping Alarm has to be installed; analogue to the dead mans alarm in the engine room. The maximum time span is 11 minutes. No reset means alarm for the other nautical officers. At some integrated bridge systems touching any function button resets the timer.

10 Dangerous Zones

Dangerous zones and spaces are defined as the areas and spaces where the risk of fire or explosion due to the existence of fire hazardous liquids, gases, or explosive dust, may exist.

Such spaces are for instance:

- the tanks of a tanker, and the deck above, the area near the hose connections, the pump room,
- the car decks of a ferry, where motorcars are parked with fuel in their tanks,
  the space for water scooter or other toys on a yacht,
  the helicopter deck with refueling equipment on an offshore unit,
  the paint store on a ship
- the hold of a cargo ship where certain dangerous goods are stowed.

The cheapest solution to deal with possible dangerous situation is not to install electrical equipment.
The dangerous zones are divided in Zones 0, 1 and 2.

Zone 0. Areas and spaces where an explosive atmosphere exists continuously.
Examples are cargo tanks with the surrounding ballast tanks of a crude oil tanker, a product carrier or chemical carrier, ships which transport liquids with a flashpoint below 60 °C. On gas tankers for LPG or LNG, the tanks with the surrounding insulation spaces.

Zone 1. Areas and spaces where an explosive condition is possible during normal operation. Examples are spaces around cargo tanks of tankers with a cargo flashpoint below 60 ° C, i.e. spaces which are separated from "zone 0" by single bulkhead. Also pump rooms and closed or semi closed spaces where cargo lines are passing through. Also areas on deck, within a 3 meter radius from cargo tank opening, a cargo valve or flange, and outlets of pump room ventilation, a layer of 2.4 meters above a cargo tank deck, and a 6 meter radius from a high velocity vent of a cargo tank.

Zone 2. Spaces where an explosive mixture is non existent during normal operation, and in case it nevertheless happens, this is only for a short period
In this zone, tank measurement has to be installed "intrinsically safe" (blue cables) and the controls have to be explosion proof (EXD IIB T4).

Zone 2 is acceptable for dry cargo ships and for car decks of ferries but only if the spaces concerned are adequately ventilated. Dangerous conditions are considered none existing during normal operation.

Warning: Liquid LNG and the vapors of kerosene are heavier than air, and can flow through an opening to a lower deck or space.

Intrinsically safe circuits are circuits with power level limited that it can not cause ignition of the dangerous gasses. Intrinsically safe cables have to be routed separated from power and control cables to avoid that they pick up power signals from the non intrinsically safe circuits.

Explosion proof control station of cargo pumps at cargodeck

Explosion proof circuits are circuits and power supplies to electric motors and electric lighting equipment which are designed so strong and with air gaps that an explosion within the enclosure will not ignite any gas outside the enclosure. Further the temperature of any part of the equipment will not exceed the temperature class for the specified cargo

Gasses are divided in classed as follows:

- Group I Methane, as van be expected in mines
- Group II General Industrial Gases and gas of inflammable liquids and inflammable solids.
- Group IIA Propane
- Group IIB Ethylene
- Group IIC Hydrogen

Equipment for use in dangerous zones has to be chosen in accordance with the gas group, and in accordance with the maximal temperature as defined for the cargo. This temperature must be below the flashpoint of the gases which can derive from the cargo as on the cargo list.

Temperature Classes and maximal temperatures are as follows:

- T1 <450 ◦C
- T2 <300 ◦C
- T3 <200 ◦C
- T4 <135 ◦C
- T5 <100 ◦C
- T6 < 85 ◦C

11 Acceptance Tests

Commissioning means to make the installation working, the testing of the components and finally of the complete installation, and is carried out in the following phases.

Testing has to be carried out as early as possible in the program, to have leeway in case a problem arises. Another reason is that testing becomes more expensive when the time proceeds.

Factory Acceptance Test (FAT). The first test of equipment is carried out at the premises of the makers. This can be a simple single component like a valve, but also a complete generator, or switchboard, a complete control and alarm system.

Factory acceptance test low voltage mainswitchboard

The makers have to show the installation in good working order to the Owners and the Classification Society. Large electric motors, so far as not type approved, are tested at the manufacturer's workshop. To check the quality of high Voltage equipment such as generators, switchboards, transformers, frequency transformers and large motors, first get an insulation test, secondly a high Voltage test and afterwards an insulation test again. A heat run is carried out to check the rising in temperature in the windings of generators motors and transformers. In the end all equipment, as far as possible, has a function test.

Harbor Acceptance Test (HAT).

After installation on board, connected up and tested again, still at the shipyard afloat, the various systems or modules have to be tested with the ships own electric power. The main aim is to show that the various components, from different makers can work together in an acceptable way.

This concerns load tests of diesel. Generator and switchboard are working together for the first time. Diesel generators alarms and shut down systems. Power management. Bridge control systems. Propulsion engine alarms and shut dows. In general the total installation is tested in port before going on sea trials.

Alarm systems and controls are to be checked thoroughly. Also watertight doors, fire doors, fire detection, communication, lighting and emergency lighting, automatic starting pumps, emergency generator etc.

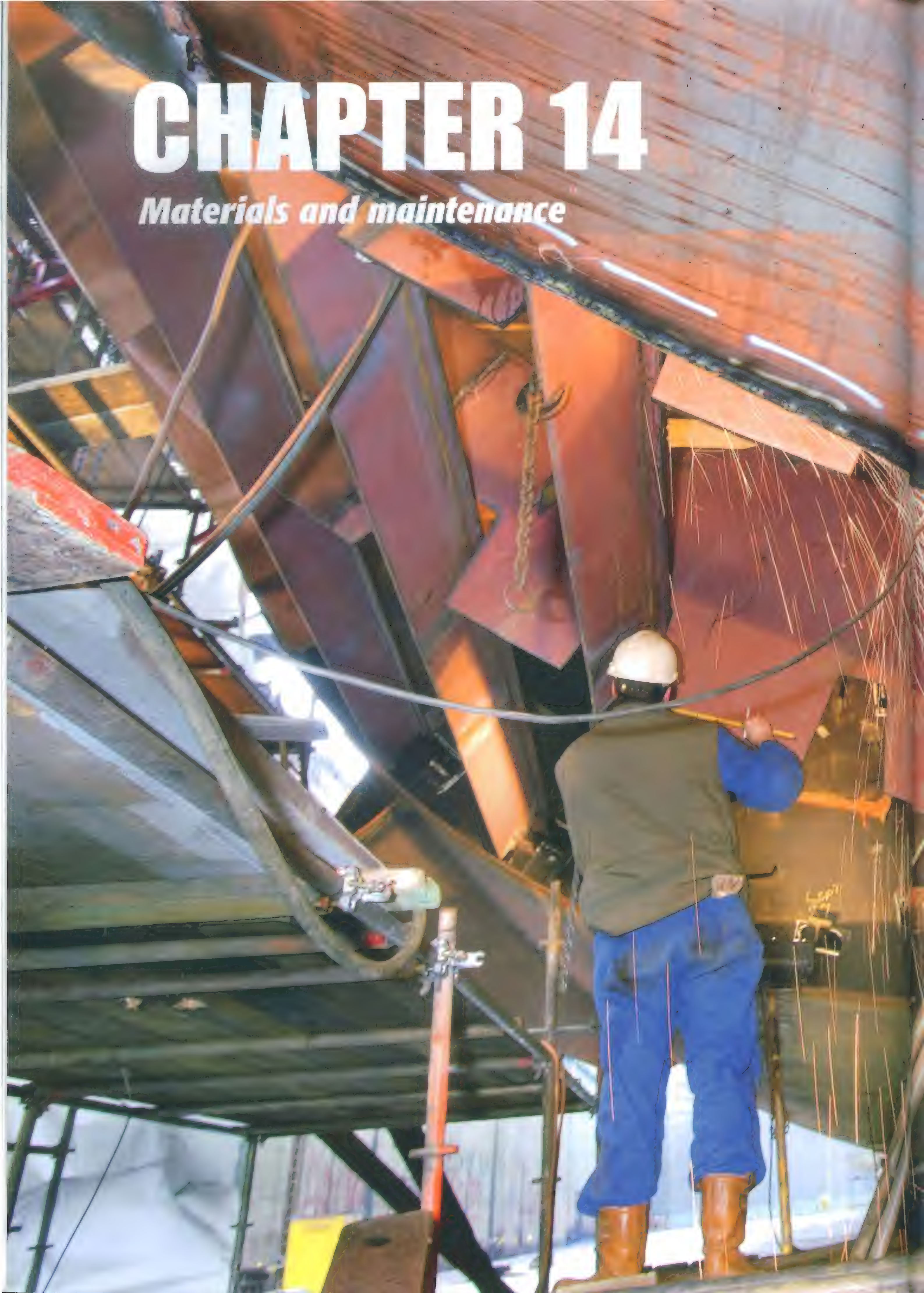
For financial reasons many systems ands equipment are tested at the yard.

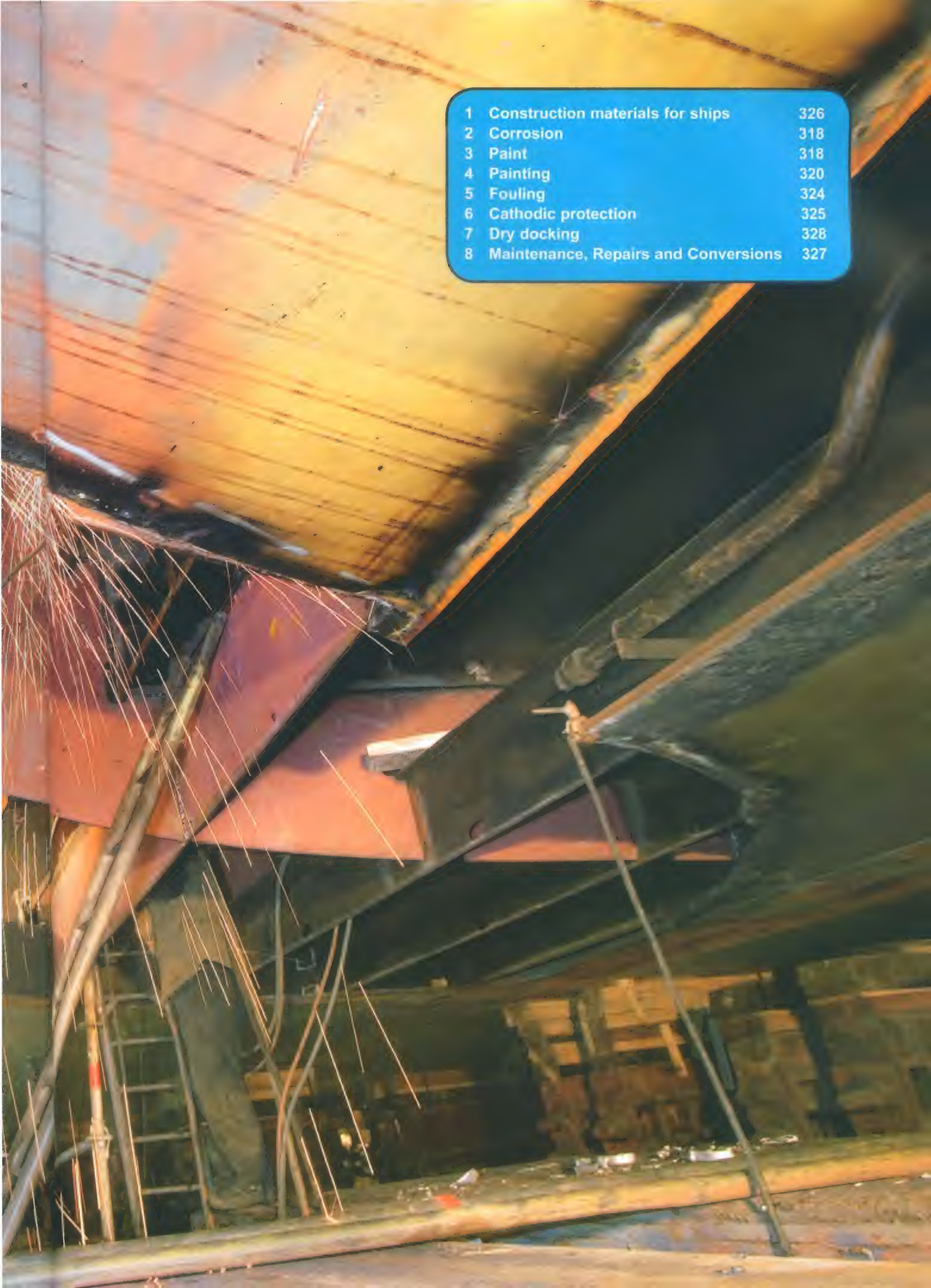
Sea trials Acceptance Test (SAT).
After the successful completion of the harbor acceptance tests, sea trials are to be carried out to show that the ship can perform as an independent unit. The sea trials comprise the tests which only can be done at sea: speed trials, maneuvering tests, crash stops and steering tests.
A reliability test has to be carried out during 6 hours to check that the ship can perform without (important) alarms. Fuel consumption is measured, and many data are collected for future reference. The smoke detection in the enginerooms is tested using a smoke source, to check if smoke is detected when the ventilation and the engines are working at full power.

Recording engine data

CHAPTER 14

Materials and maintenance





1. Construction materials for ships

This chapter is not about materials science, but about what materials are used in the construction of ships and their characteristics. The emphasis will be on corrosion, prevention and maintenance.

1.1 Wood

Until the end of the 18th century, wood was the only construction material for ships. Some of these ships had longer lives than their steel successors. Mine hunters have used wood as a construction material the longest of all the large ships. The only wood still found on modern ships is used for dunnage, deck covering, stairs and interior finish, especially on cruise ships. Though there certainly are very hard types of wood that do not rot, most types of wood must be protected against rotting. Wood used on decks does not get slippery and, unlike metals, it is not weakened by fatigue. To avoid excessive corrosion a wooden over-lay on a steel deck must be applied with great care. Water must not be allowed to become entrapped between the wood and deck.

1.2 Steel

Since early 1800 the construction of vessels gradually evolved from wood, via composite building (wooden planks on steel frames) to 100% steel. Composite building was a mixture of iron framing and wooden side shell and deck, which allowed the builders to build vessels up to approximately 90 meters in length. The "birth" (1830) of the steam engine for ships speeded up the actual use of iron throughout the construction of the vessel. An important milestone was reached with the building of the famous **"Great Eastern"** between 1853 and 1858. A ship with a length of 200 meters, a beam of 25 meters and a depth of 17 meters. From 1875 the steelmaking process gradually improved to what it is today.

Up to now steel is still the most popular material for the construction of ships because of its:

- technical and economical benefits
- strength
- suitability for welding
- adequate resistance to brittle fracture
- low cost and availability

Steel-making process

Various types of steel are fabricated on the basis of iron (ore) and/or scrap materials, in a steel-making process in which the material is heated up to approximately 1600 °C. Then the refining process is initiated. Within this refining process certain excessive elements such as carbon, sulfur and phosphor will be removed in the form of so-called "slag". Depending on the quality and type of steel needed, the refining process within a chosen steel-making process (basic oxygen converter, electric furnace & open hearth process) will be completed. The differences in strength, toughness, hardness and weldability will be obtained by the addition of particular elements during the steel-making process in combination with the heat treatment during the fabrication of the plate material, forgings and castings. Additions can contain carbon, silicon, manganese, nickel, vanadium, chrome, etc.

Steel types

Steel used as a construction material for ships and other structures can be subdivided into groups:

a. Plate materials and profiles

- Mild Steel (MS)
  Yield strength 235 N/mm²
- High Strength Steel (HS)
  Yield strength 265 - 390 N/mm²
- Extra High Strength Steel (EHS)
  Yield strength 420 - 690 N/mm²

Yield strength is the maximum stress without creating plastic deformations and is used by designers to establish the actual structural member dimensions.

Flat bars and bulb flats, being lifted using a chain

b. Steel forgings
Typical examples of forgings are propeller shafts, rudder stocks, engine components such as crankshafts, piston rods and crossheads etc.

c. Steel castings
Castings are fabricated for complex configurations such as stern frames, complex rudder components, anchors, pump casings, etc.

Stainless steel
Stainless steel is an alloy of steel, chrome (Cr) and nickel (Ni) and sometimes other elements. The surface of the steel is a neutralization layer, which is an oxidized skin, the color of the metal. This protects the material beneath it from oxidation (corrosion). Stainless steel is more noble than ordinary steel and will therefore corrode less.

1.3 Aluminum and its alloys

Aluminum is a very soft metal, but by choosing the right elements to form alloys, the strength and stiffness can be increased significantly. Aluminum is also non-magnetic, making it suitable for mine hunters. Even though aluminum is not a noble metal, corrosion is limited because the metal is covered by a very dense oxide layer that protects the rest of the metal. If chemicals or electric currents remove the oxide layer, then corrosion will take place rapidly. The main advantage of using aluminum is its low weight. Despite the fact that aluminum is much softer than steel, it is much more difficult to work with. A drill gets stuck easily, it is much more difficult to get the surfaces smooth, a grindstone is soon clogged and it is impossible to weld it with common welding apparatus. Aluminum is utilized for complete upper parts of passenger ships, mine hunters, yachts, lifeboats, high-speed light-weight motor ships and for parts that need to be light-weight or non-magnetic like the wheel house of a fishing vessel or the surroundings of the standard compass on larger ships.

1.4 Copper and its alloys

Brass
Brass is an alloy of the moderately noble copper and the less noble zinc. Aggressive water like seawater dissolves the zinc leaving the remaining copper very porous. Therefore brass is **never** used for parts that can come in regular contact with seawater. For contact with fresh water and oil, brass is suitable for use in nipples, thermometers, manometers and many other shiny appliances. The binnacle of the standard compass is also usually made of brass.

Bronze (gun metal)
Bronze is an alloy of the moderately noble copper and the less noble tin. Bronze is **seawater resistant** and is therefore used in propellers, valves, coolers and almost all other parts that come into contact with seawater. Today, the ship's bell is still made of bronze, but better alloys have been developed for the propellers. Bronze is still common in heat exchangers and pumps. Bronze is more noble than steel (iron) and can therefore affect the ship's steel. In very aggressive water, tin tends to slowly dissolve. This causes a manganese-bronze propeller to roughen slowly.

Materials for propellers
Today every propeller factory has its own alloys for the different applications of propellers. Usually these alloys are similar to bronze, but with a more complicated composition. In almost all cases the alloys contain little or no iron (non-ferro alloys) and behave nobler than steel, which can cause corrosion of the steel. In exceptional cases, the propellers are made of stainless steel. The strongest today is a **copper-nickel-aluminum** alloy.

Materials for heat exchangers
The housing, pipes and tube plates of a tube heat exchanger are almost always made of copper containing non-ferro alloys. In plate heat exchangers, the plates are made entirely of stainless steel or titanium. In both cases, the alloy used is nobler than steel, which can be degraded by it. Heat exchangers can be found in the piping systems inside the ship, but also in a sea-chest, a box in the ship's shell that is open to seawater.

1.5 Synthetic materials

There are so many synthetics that it is impossible to treat them all in one paragraph.

In general, synthetics are not sensitive to corrosion. However, **ultra-violet** radiation in sunlight and ageing can degrade the compounds. Synthetics are a-magnetic and cannot be welded. In yacht-building synthetics are common. On larger ships, synthetics are used for piping systems because of their inability to conduct electricity and their insensitivity to corrosion.

Nowadays paint is also largely synthetic. The ropes are not made of manilla anymore, but of one of many synthetic fibers. Synthetics are sometimes flammable, but are always weakened by heat more than metals. Metals like iron and aluminum can burn like torches and, when that happens, cannot be extinguished. Luckily metal constructions do not catch fire easily.

A commonly used synthetic construction material in the marine world is **Glass-fiber Reinforced Polyester** (GRP). This is a composite material, consisting of woven or chopped (glass) fibers bound together by polyester. Other combinations of fiber and binder material are also used, but mainly for high-tech applications.

GRP is mainly used for parts where weight or non-corrosive properties are important. With the use of a mold it is possible to make complex shapes. Because of this expensive mold, GRP products are usually standard parts, produced in large series, like piping, watertight doors, etc. Even complete hulls of smaller ships (e.g. lifeboats, fast rescue boats, yachts, minesweepers) are built in GRP.

2. Corrosion

2.1 The corrosion process

From metallurgy it is known that iron is extracted from iron ore in blast furnaces by removing the oxygen from ore with a carbon-excess (coke). Corrosion is the reverse of this process; the metal recombines with oxygen or, sometimes, with other compounds. In many cases the result is a dense oxide-layer that protects the metal underneath. However, in the case of iron the oxide is converted to a ferro-hydroxide by water. This gives the underlying metal no protection against further corrosion.

Corrosion can be accelerated if organisms are present on the metal surface. Outboard, this fouling increases the ship's resistance and inboard it can clog piping systems and exhaust boxes.

Microscopic image of rust

Corrosion can also be accelerated with an **electric current,** and with **structural stress**.
The remainder of this chapter will be devoted to steel corrosion, because steel is highly sensitive to corrosion.

To protect the ship against corrosion, the following measures or combinations of them are taken:
- applying a protective layer (paint)
- cathodic protection by using impressed current or sacrificial anodes
- the choice of other materials so as to reduce potential electrolysis.
- applying anti-fouling paint.

2.2 Protective layers

A protective surface layer can counteract, stop or reduce the extent of the corrosion process. One of the following methods can be chosen:

- Temporary protective layers like conserving oil or grease. This method is mostly used in spare engine-parts.
- Inorganic top coats like an anodized layer (a very strong oxide layer) or enamel.
- Organic top coats like epoxy paint (2-component) or conventional paint (1-component).
- The first coat to be used as a primer to initially protect the steel against corrosion.

Ships usually apply paint as the protective layer.

3. Paint

3.1 General

Paint is a liquid product that is meant to be applied on objects in a usually relatively thin layer. During and after applying the paint, it creates a film that has the tendency to tighten into a thin continuous layer. On drying this film becomes a solid hard or tough layer that protects the surface it is covering from corroding. Paint is also used to embellish objects. Paint can be divided into:
- conventional paint
- physical drying paint
- oxidative drying paint
- chemically active paint or binary paints

Corroded construction parts

3.2 Conventional paint

Real old-fashioned oil paint was made from linseed oil and turpentine. Later these were replaced by synthetic components. **Single pot paints**, that behave similar to oil paint, are called conventional paints. The paint can be used immediately after the can is opened and the contents stirred. Leftover paint can be stored in the closed can for future use.

The conventional paints dry because:
- the solvent evaporates (physical drying)
- the binding agent reacts with oxygen from the air (oxidative drying and / or polymerization)

Examples of conventional paints used on board:
- alkyd paint, chemical drying
- acrylic paint, physical drying
- vinyl paint, physical drying
- modified alkyd paint or alkyd resin slags, chemical drying

In general, conventional paints contain the following components:
- binding agent
- pigment
- solvent
- additives and fillers.

Today, more and more environmental restrictions are being implemented related to the use of zinc chromates, lead, etc. Also chlorinated rubber systems and vinyl systems are no longer in use because of the high content of volatile organic compounds (e.g. toluene, benzene), restrictions, however, vary from country to country.

Water is used in both one- (acrylics) or two-component (water-based epoxy) water-based products. These coatings, however, are not solvent free. In solvent-free coatings (epoxies) thinner is not normally used and if it is used, then only very little is added to extend potlife of mixed material for the application method depending on climatological conditions (temperature).

Binding agent

The purposes of the binding agent in the paint are:

coherence of the paint
connecting the pigment
adhering the paint to the base
influencing characteristics like gleam, elasticity, mechanical strength, wear resistance, resistance against chemicals and sunlight.

Binding agents can be composed of drying oils, synthetic resins, latex or a combination of these.

Pigments

Pigments are solid powders that give the paint its color and coating properties. Furthermore, the pigments often also prevent corrosion.

Examples of these are:
zinc-chromate (yellow),
- zinc-phosphate,
- zinc powder (grey),
aluminum flakes in primer,
- glass flakes,
- lead seal (in red lead, orange, toxic, banned!)

Pigments can also be additives that contribute to characteristics of the paint like gleam, filling, scouring and strength.

Solvents and thinners

Solvents and thinners are volatile liquids or mixtures of volatile liquids that dissolve and dilute the binding agent. After the paint is applied, they evaporate out of the solution. In general the vapors are harmful to health and environment. These compounds are almost always inflammable and can form explosive mixtures with air. There are strict regulations for ventilation and breathing-protection when working with these compounds in closed spaces.

It is difficult to distinguish solvents from thinners; the words solvent and thinner are often interchanged. Thinner is a much used dilutent.

A solvent is used for the cohesive substance and thinner only dilutes the paint. It all depends on the kind of paint. Chlorinated-rubber paint can be dissolved but also diluted.

Fillings and additives

Additives are used to influence the characteristics of the paint like a mat surface, a rough surface (anti-slip paint), protection of the underlying material against heat, prevention of sagging and counteracting film forming.

3.3 Binary paint

In binary paints or two-component paints, the film forming and drying take place by a chemical reaction between **two components**. A better name for these types of paints would be "chemically active paint". The components are:
- the base component
the hardener

The temperatures of the surroundings and the material to be painted have an important influence on the rate of the reaction. In dual-component paints, the two components are delivered and stored in two different cans. After the base component and hardener of the epoxy paint have been properly mixed, the mixed material should be given a certain time prior to application.This time is called "**introduction time**"; normally this takes about 10 minutes and is mentioned on the data sheet of the coating supplier. Leftover paint hardens and becomes useless. Examples of these types of paint are polyurethane and epoxy-paints.

3.4 Comparing the two paint systems

The choice for a conventional or binary paint is governed by a large number of factors. The physical and chemical properties of binaries are superior to the conventional paints. But a tougher layer, longer gleam and greater resistance to water and chemicals are not equally important to every shipping company.

Mixing with a blender until the paint gets a uniform color

Some arguments that can influence the choice of paint-system are:
- the price of the paint
- price of the pre-treatment
- purpose of the ship
- is the painting done by the crew (or the shipping company), during a voyage or during docking

This last point depends on:
- the number of crew members
- where will the ship be sailing:
- in tropical areas; the crew can do a lot of maintenance;
- in arctic areas maintenance cannot be performed in water, but only in a dry dock.

The following becomes important when the crew does the painting:
- Conventional paint is simpler in use than binary paint.
- Single pot paint is easier to use than dual component paints.

4 Painting

4.1 Pre-treatment

For a good painting-result it is important that the material that is going to be painted, is pre-treated. Painting should be done under conditions where the effect of temperature and humidity changes is small. This is the reason that more and more ships are being painted in closed and acclimatized spaces. The pre-treatment is the base of a good protection for the material. The better the material is cleaned, the better the result will be. A good paint-system on a bad base is of little value. The base material can be cleaned in the following ways:
- with hand tools
- mechanical cleaning (with machines)
- chemical cleaning, especially degreasing
- thermal cleaning
- sandblasting / gritblasting
- waterjets

Hand tools
Manual cleaning is done with scaling hammers, scrapers, sandpaper and wire brushes. This pre-treatment method is very labor-intensive and qualitatively not very high-grade. It is used predominantly for local repairs of the paint-layer and sometimes for the treatment of welds and places already treated with an abrasive wheel.

Mechanical cleaning
This is done with mechanical scaling hammers, rotating wire brushes, abrasive wheels and abrasive discs. Onboard, needle-scaling hammers or chipping hammers are used almost exclusively. Of all the types of mechanical scaling hammers, this one is the best, although it is not very fast. The roughened surface gives a good anchoring for the paint layer.

Rotating wire brushes, abrasive wheels and abrasive discs can yield the same result as the needle-scaling hammer, with the difference that the surface may become polished.

Seven years of damage to the paintlayer. The cause: badly protected welded seams which may be caused by insufficient cleaning after welding prior to painting

If the mill scale is not properly removed, it will eventually let go

If holes or cracks are not welded properly this may cause problems with cleaning and pre-treatment. This in turn can cause small blisters, that cause detachment of the paint layer.

The paint layer is loosening from a bad base or incorrect pre-treatment

Manual cleaning

Rotating wire brush

A pneumatic scaling hammer

If the metal surface is too smooth, the mechanical bonding between the metal surface and coating will be poor, leading in most cases to premature failing of the coating system. Almost all methods of cleaning with mechanical devices require breathing and hearing protection. The waste of removed old paint layers should be collected and disposed of properly.

Chemical cleaning

Chemical cleaning removes the old layer of paint and rust. For local paint jobs, paint-stripping compounds are used. In manufacturing, the cleaning is either done with acids or with staining. In all cases the cleaned material should be thoroughly rinsed with fresh water.

Thermal cleaning

For local removal of paint, a heat paint stripper can be used. The heat softens the paint, which can subsequently be removed by tools. The paint stripper is not used on a large scale because of the fire-hazard and the toxic vapors that are released upon heating.

Gritblasting

Gritblasting is done by blasting granular materials at high speed with high-pressure air against the steel. The material is cleaned thoroughly and the surface is roughened which is essential to achieve a good mechanical bonding with the coating. The roughness can be adjusted by adjusting the size of the grit material during the gritblasting. The surface becomes covered with microscopic pits that are good for the tacking of the paint layer. The first layer of paint should be applied immediately after gritblasting to prevent moisture in the air forming a new layer of rust on the bare steel.

Gritblasting is not done on a large scale onboard because it requires a special installation. It can be done in drydock though. This method is suitable for treating large areas; 20 m^2 per hour is feasible. Another advantage of gritblasting is that it can be used to remove the rust from complicated constructions, where other tools can not reach every nook and cranny. However, removing thick layers of paint or rust with this method takes a lot of time and is therefore not efficient. In the dry dock, gritblasting is usually limited to the outside of the shell and possibly the tanks. When gritblasting, it is important to pay attention to personal safety-protection for the ears, eyes and lungs.

Waterwashing and Hydroblasting

Of the following cleaning methods waterwashing is the preparation method mostly in use. The installation consists of a high-pressure pump, hoses and a gun or lance.

Till a pressure of 350 Bar it is called low-pressure waterwashing. It is very successful in removing salt deposits, loose paint, algae, and other relatively loose dirt and deposits.

From 350 till 700 Bar it is called high-pressure waterwashing. With these pressures it is possible to remove heavy sticking sea-growth like barnacles, and to remove intact blisters in the paint.

From 700 till 1700 Bar it is called waterblasting or hydrojetting, often used in combination with a gun with a rotating cutting head. Rust and barnacle bottoms are removed.

From 1700 till 2350 Bar it is called ultra-high pressure waterblasting. Again even better results. This method is gradually superseding gritblasting due to the environmental impact of gritblasting. The cost of grit disposal is placing it out of the market. Special installations can produce more than 2500 Bar, then also the millscale gets off. Cutting steel is possible with a water pressure of 4000 Bar.

Local gritblasting. In some countries sandblasting is still applied, in most countries, however, it is no longer allowed due to health (lung) problems.

Advanced technique for gritblasting, with special care to prevent excessive inconvenience caused by 'dust'.

High pressure water washing

All above depend on the surface quality and the requirements. Waterblasting production in sq.m/min or hour, is relatively low, set against gritblasting. The skill of the blaster is important. When blasting, a mistcloud obstructs the view, and causes missed spots.

Advantages of waterblasting against dry-blasting
- Better **removal of salt** deposits. Little dust
- No damage to surrounding areas
- Feathering possible, the blasted area can meet the existing coating gradually, this means no hard borders
- The water pressure warms the water, and so the surface. This reduces the fly-rust and leaves a dry and clean surface
- The dry dock can be cleaned with water. Removal of paint remains by sweeping. No large quantities of (heavy) grit to be disposed of

Disadvantages:
- **No anchoring** pattern in the treated steel
- Water accelerates oxide development. For some kinds of paint this is not acceptable
- Production is considerably lower than dry blasting
- Tools are vulnerable to damage, and difficult to repair. Dry blasting requires simple tools and an ordinary air-compressor

Hydro-blasting

4.2 Applying the paint layer

Before the paint is applied one has to make sure that:

- The surface is clean of moisture, dust and grease
- The surface shows no signs of condensation, and there is no opportunity for the forming of condensate
- The outside dewpoint temperature does not exceed 40 °C, or fall below the minimum processing temperature of the paint. Some paints can be used even at -5 °C
- The right paint is prepared; the binary paint is mixed in the proper proportions
- The paint is stirred well before use, preferably with the aid of a mechanical mixer
- The correct tools are being used: brush, roller or spray

The paint spray is only used for large areas. Spraying makes it possible that the paint layer is distributed evenly, and the layer thickness can become bigger than when a brush or a roller is used.

The stripes in the brush-"trail" should even out by themselves. This is not the case shown here.

Painting the deck with a brush

If the paint is applied too thick, it will sag.

Painting with a brush. If the painting is done in a closed space, breathing protection is necessary.

Applying paint with a roller

Paint-spraying

The two sprays are too close to each other; the sprayer on the left is too close to the ship's hull.

Welding or burning on the other side will cause damage to the paint-layer.

The material that is going to be painted should be at least 3 °C warmer than the dew point of the surrounding air. This can be tested by breathing against the surface. If there is condensation on the surface, it has to disappear within minutes.

The **dew point** is the temperature at which condensation starts, because at that temperature the maximum water-vapor pressure is reached. The relative humidity is then 100%. If the temperature then drops below the dew point, the water will condense on the coldest surfaces.

4.3 Thickness of the layer

The thickness of the paint layer can be expressed as the wet layer-thickness or the dry layer-thickness, usually reported in micron or mm,
1 micron. (1mu) = 0,001mm

This equation shows that if a paint with a high content of solids is used, fewer liters can cover more m² with a protective layer against corrosion. If the paint is applied with airless spray, the loss of paint in the form of mist can be 20% -30%.

$$\text{Theoretical coverage (m}^2\text{/litre)} = \frac{10 * \text{solids in \%}}{\text{dryfilm thickness}}$$

The spray-loss factor is influenced to a large extent by:

- shape of the construction
- weather circumstances during application
- experience/skill paint-applicator
- cleaning and use of remains of the 'empty' paint cans

To achieve a proper protection of the steel, the following protective paint system minimum thickness, based on epoxies, is recommended:

- inside accommodation: 100 micron
- outside, vertical areas under salt attack: 250 - 300 micron
  outside horizontal areas under salt attack: 200 micron
- underwater, without antifouling: 250 - 300 micron
- inside cargo tanks (epoxy systems) 300 to 400 micron, however, very much depending on the type of paint and the supplier's requirements.

4.4 Types of paint

– **Finish paints**

Finish paints are the final coatings and include anti-fouling paint.
Finish paints can be categorized by use i.e. bottom, boot topping, topside, deck, tank, etc.

– **Shop primers**

Shop primers are used as temporary protective layers directly after the steel plates have been rolled, cut and sandblasted.
Requirements for shop primers are:

- To prevent the forming of **rust** during the construction of the ship.
- They must either be welded through primer and be able to absorb the speed of the welding
- without the forming of gaseous holes.
- The shop primer should also be suitable as a **base** for the final paint layers.
- No production of harmful fumes when being welded.

Today only binary shop primers (low zinc ethyl silicate) are used. The shop primers give the gritblasted steel up to nine months protection, depending on the local conditions.

– **Zinc containing Ethyl Silicate or Zinc Epoxy**

This is used if there is a great risk of mechanical damage. The zinc sacrifices itself when the layer is damaged. It is applied as a single layer with maximum thickness of 75 and 50 micron respectively. It is often used in tank tops and hatches.

4.5 Painting systems

A steel-conservation system is built up of a protective primer, the coating and the finishing layer. This system combines active (see section 5) and passive corrosion prevention. Passive corrosion protection means that the metal is sealed off from the influence of water, air and chemicals. Each type of paint is more or less passively protecting. The permeability of a dry paint film depends on the type of paint, but even more on the layer thickness and the number of layers. The higher the number of layers and the higher the total thickness, the less is the permeability. In general the selected coating system and the area of the vessel (underwater area / topsides / ballast tanks, etc.) determine the number of coating layers.

5. Fouling

The main purpose of anti-fouling is to keep the underwater shell free from marine growth.
It is also to prevent **organisms** from damaging the paint layer and the steel underneath. As a coating it also offers (some) protection against corrosion.

5.1 Fouling

Fouling is an umbrella term for water plants (algae and weeds) and animals (barnacles, polyps, mussels, anemones). The number of organisms that result in fouling of the hull is as high as 4000 to 5000. The fouling can be divided into two categories according to the size of the adult organisms:

- macrofouling, made up of animals and plants
- microfouling. This is a slimy mass, a sticky mix of bacteria and other micro-organisms.
- The adhesion of the microfouling is weaker than the adhesion of macrofouling.

5.2 The ship's shell, the ideal surface for fouling

Spores and larvae easily deposit onto slow-moving rough surfaces. A smooth surface in combination with high speed is a less ideal foundation. Some chemicals and metal-ions like those from copper are toxic for these organisms.
The growing organisms get their nourishment out of the water flowing along the hull. A ship that is moving slowly (0-10 knots) has the ideal combination of a solid surface and a good supply of food. The growing process of fouling is quite intricate. It depends on geographical, climatological, and oceanographic circumstances, the season, nature of the material and the sailing pattern. For instance, the **sailing pattern** of a container ship (short berthing time) differs from the pattern of a dredger (alternating high and low speed, long and short stops) which again differs from the pattern of a supply-vessel (long stops, interrupted by intensive sailing).

Fouling increases the ship's resistance and reduces the velocity by 10 or 15% at equal engine power. To keep the original velocity, the engine-power has to be increased by 23-38%. The fuel consumption increases then by 25-40%.

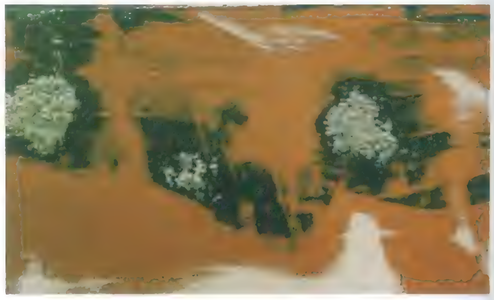
5.3 The purpose of anti-fouling

The main purpose to apply anti-fouling, is that it saves money. Fouling leads to many problems affecting efficient operation, as it increases the ship's frictional resistance:
- Loss of speed and/or increase of power required to maintain speed. Fuel cost can go up by as much as 40%.
- Increased dry docking frequency, and longer stays in dry dock.
- Reduced maneuvrability.
- Increase of engine-wear.
- Increase of NOx and SOx emission
- Higher cost of in-water examination for Class, or no acceptance of this examination, possibly resulting in a dry docking.
- Blockage of sea-inlet gratings, and thus less cooling water for the engine(s).
- Damage to paint substrate and consequently corrosion of the hull.

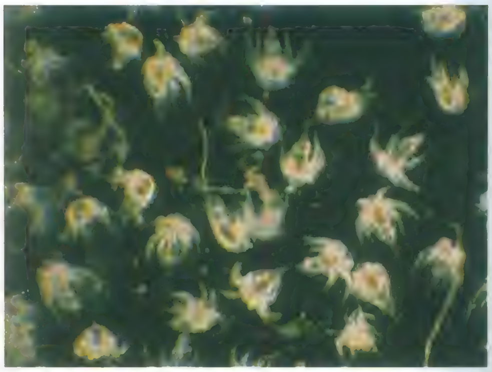
From the above, it is clear that application of anti-fouling is useful. The cost of application is easily set off against the additional cost of fuel and loss of time.

Anti-foulings contain biocides, which kill the larvae of marine growth, such as barnacles and other shells, and algae. The normally used biocides are **copper** or copper derivates.

Mussel fouling



Fouling in places where the anti-fouling has gone



Larvae

Acorn shells, mussels and other shells

Green algae fouling

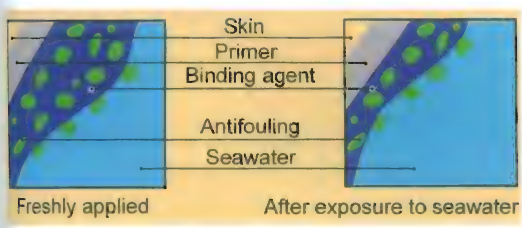
5.4 Types of anti-fouling

– **Self-Polishing**

Most anti-fouling types, now in use, are of the self-polishing type. Self-polishing means that due to the speed of the ship the outer layer of anti-fouling paint, softened by the sea-water, very slowly dissolves, taking fouling - if any - with it. The process of softening, hydrolysis, continues deeper into the paint layer. When the paint is totally dissolved, and the substrate is at the surface, fouling starts. The total necessary layer thickness, can be calculated from the **polishing rate** and the ship's **service speed**. For classes of ships each with their own speed category, different polishing rates are developed, to achieve a taylor-made anti-fouling. Containerships with a speed of 25 knots need another type of anti-fouling than the dredger with 5 knots or the bulk carrier with 15 knots. The thickness of the layer of anti-fouling decides the working time.

To enable overcoating in dry dock, it is important that this layer is still present. If not, so-called "polished through", the substrate, usually an epoxy with an adhesion coat of an epoxy/vinyl mixture, becomes too hard, (and possibly fouled), and provides insufficient anchoring for the new paint.

Self-polishing anti-fouling creates, due to the polishing effect, a smooth surface. This, in itself is an advantage, as it keeps drag at a constant level, and so the friction-resistance.



Self-polishing anti-fouling

– **Hard Anti-fouling.**

This anti-fouling consists of a matrix type binder mixed with biocide. When the ship is in the water, moving or not, the biocide is leaches out, and killing the larvae of the marine-growth.

When the biocide is not leaching anymore, the fouling starts. Normally this process goes on for two to three years, after which another coat of anti-fouling needs to be applied. Through the years there is a huge build-up of paint, and a growing roughness.

Non-Stick Paint - Fouling Release Paint

A new development (2006) is a finishing underwater paint, so smooth, that fouling, when it has settled, starts to drop off when the ship's speed exceeds 5 knots.

At 15 knots it is all gone.

The paint is based on a silicon elastomere, and is a two or three component paint, depending on the supplier. It should not be called anti-fouling, but a fouling release coat. When undamaged, theoretically an unlimited lifetime.

Not only ship's hulls are painted with this kind of paint, but also the propellers, as they also tend to get fouled. The propeller smoothness is as important as the hull smoothness: the revolutions times of the area of the propeller is a figure of similar magnitude as the underwater hull area times the ship's speed.

The above paint system is proven to be very cost-effective on fast ships, such as the large container ships, navy ships, and fast ferries. With this type of anti-fouling, the new condition of the hull (or even better) can be maintained throughout the ship's life, whereas ships with conventional anti-fouling through the years slowly build up the hull roughness resulting in higher frictional resistance with the disadvantages listed above.

– **Hybrid Systems**

Between the various principles, there are also mix-forms.

Biocides are heavily under pressure. Tin containing anti-foulings were banned through IMO some years ago. In future copper will probably go the same way.

5.5 Economy

Decisions about application of expensive paint systems are mostly taken depending on who is paying for the fuel. Companies using their own ships in their own trade, such as large container ships and passenger ships, pay their own fuel. Tankers and bulk carriers and charters in voyage also. However, the latter ships often do their work in time-charters, and then the charterer is paying the fuel.

6 Cathodic protection

To understand how cathodic protection works, it is necessary to look in more detail into the corrosion process. In this undesired chemical effect, the material can react with different chemicals in its surroundings. The reactions can be divided into:

- chemical reactions
- electro-chemical reactions

These reactions take place exclusively at the surface of the metal. It is possible that microscopic pits are formed by corrosion on the metal's surface. The corrosion can also occur in existing cracks.

Anti-fouling at the end of its life and worn out. Time for repainting. The spraying pattern on the skin is still visible. The outermost layer of anti-fouling is still partly visible on the overlap. In between it has disappeared completely.

6.1 Chemical reactions

In almost all chemical reactions, there is a charge transfer between the reactants. If this exchange of charge is a local effect, then the reaction is called a chemical reaction, and the resulting corrosion chemical corrosion.

An example of this is the reaction between bare steel and oxygen from the air. A thin oxide layer rapidly covering the metal, is formed at the surface. All metals form such an oxide layer. The characteristics of this first (dry) layer are of great importance to the further course of the corrosion process, and to the adhesion of the paint layer.

If water comes into contact with the iron oxide, the compounds react to give the product **iron hydroxide** (rust). The rust is very porous, and therefore oxidation continues.

The first oxide layer of stainless materials is not affected by water. Between the metal and the oxide layer a lack of oxygen arises which is the reason that the oxide layer cannot develop any further.

6.2 Electro-chemical reactions

Many compounds have the tendency to dissolve charged particles (ions) into water. Ions can move freely in water. Compounds that always behave in this way are acids, alkalines, soluble salts, metals and some gases. A consequence of the ion-mobility is that chemical reactions and the incidental electrical current are not necessary local, they can stretch out over a much larger area. These electro-chemical reactions do not just come to a halt.

Every metal in contact with water has the tendency to generate positive ions. This makes the water more positive and the metal more negative. If a metal is less noble, it will have a stronger tendency to generate these ions and thus become more negative. Alternatively, if the metal is more noble, then it will have a weaker tendency to generate positive ions and will thus be less negative.

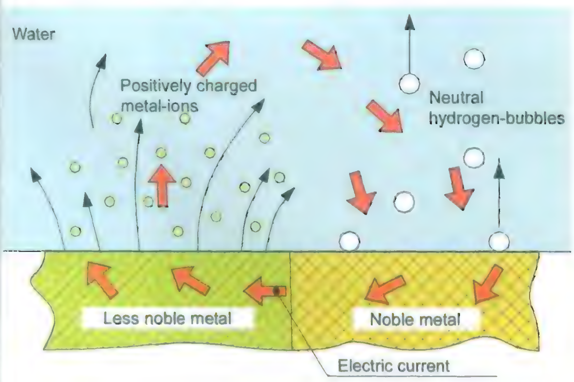
In general:
- gold is more noble than copper
- copper is more noble than tin
- tin is more noble than iron
- iron is more noble than zinc
- zinc is more noble than aluminum.

6.3 Sacrificial element (galvanic corrosion)

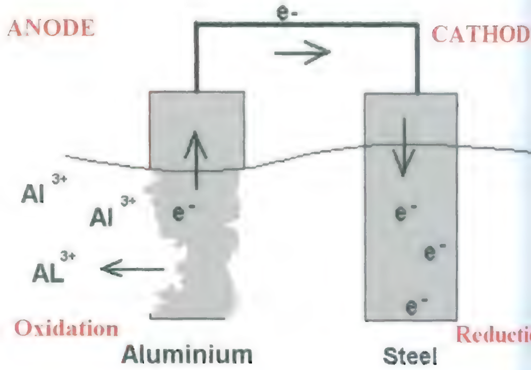
When two different metals are in contact with each other and with water (even a small amount), then the less noble metal will have a lower electrical potential than the more noble metal. This potential difference and the contact between the metals generates an electric current between the two metals, running from the precious to the less noble metal.

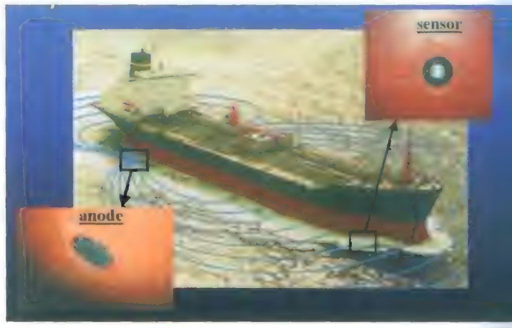
The continuous flow of current to the less noble metal causes it to generate more ions that dissolve into the water. This way the metal slowly disappears into the water. This dissolving of metal ions is called an anodic reaction and the metal that is dissolving is called the anode.

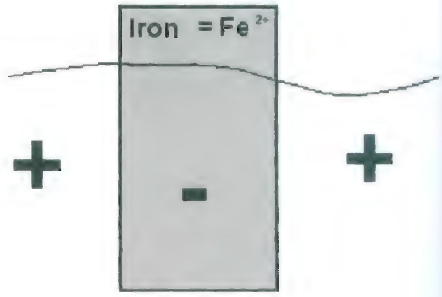
Electro-chemical corrosion can also take place if a metal is not composed homogeneously. Objects in seawater that are made of brass (an alloy of zinc and copper) are very sensitive to this; the zinc dissolves leaving a porous copper behind. This is called de-alloying. If there is no intervention, then all the anodic material (zinc) will dissolve until all of it is completely dissolved.

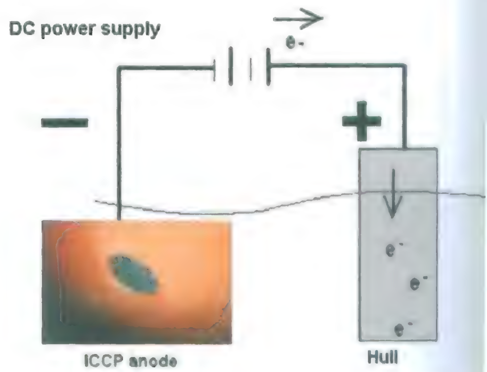


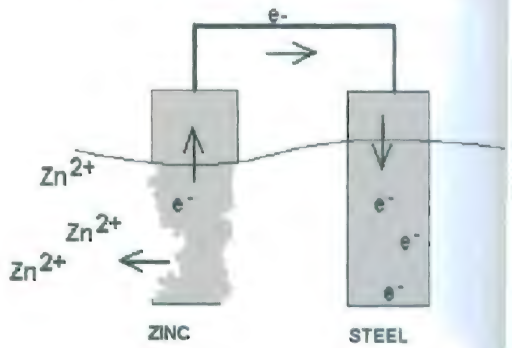
Galvanic corrosion











Electro-chemical reactions on ships can occur in the following places:

- between the propeller and the surrounding steel
- between copper-containing parts (e.g. heat-exchangers) and the steel parts of a piping system.
- between aluminum parts and the steel parts of the ship.

Electro-chemical corrosion mainly occurs at places where the paint is damaged, for example by soft contact with a muddy river bottom (Mississippi), ice, after contact with debris in the water alongside a jetty, and the normal wear through mooring and departure, tugs that come alongside etc. Turbulence, speed of the water and higher temperatures of the water and salinity increase the corroding process.

Eliminating the corrosion current can prevent electro-chemical corrosion. This goal can be achieved in several ways:

- Insulating the metal on the water side by painting it. This prevents the metal from contact with the oxygen and the electrolyte. If the paint layer stays intact, this works. As soon as the layer is damaged, the corrosion begins.
- Reversing the current by using a sacrificial anode of a very base metal
- Reversing the current by creating an opposite potential, (ICCP system:Impressed Current Corrosion Protection).

6.4 Sacrificial anodes

Cathodic protection using sacrificial anodes is called passive cathodic protection. Blocks of zinc and/or aluminum are connected to the ship by welding of cast-in steel strips, in different places. These anodes have such a low potential that they "suck" the current out of the ship's exposed steel, faster than currents can enter the skin via the copper-containing parts. The protection works by the wastage of the sacrificial anodes as they are less noble, so as long as there is anode material present the anodes work.

Sacrificial anodes on the propeller nozzle

If the paint-layer below the waterline is damaged, there will be an electric current from the water into the metal. If the damage is extensive, then the anodes will dissolve faster. When the anodes have been dissolved, the other metals (ship's steel) will start to dissolve.

Sacrificial anodes have the following:

Advantage:

- low investment costs

Disadvantages:

- the limited life-span of the anodes; 1 to 5 years and difficult to predict
- floating ice, irregularly dissolving and other damaging factors can diminish the protection quite unexpectedly. This can lead to damaging of the steel.
- there is a chance of overprotection, especially when the anodes have just been applied. This can damage the paint-systems.

Reference electrode of impressed current system seen from inside the hull

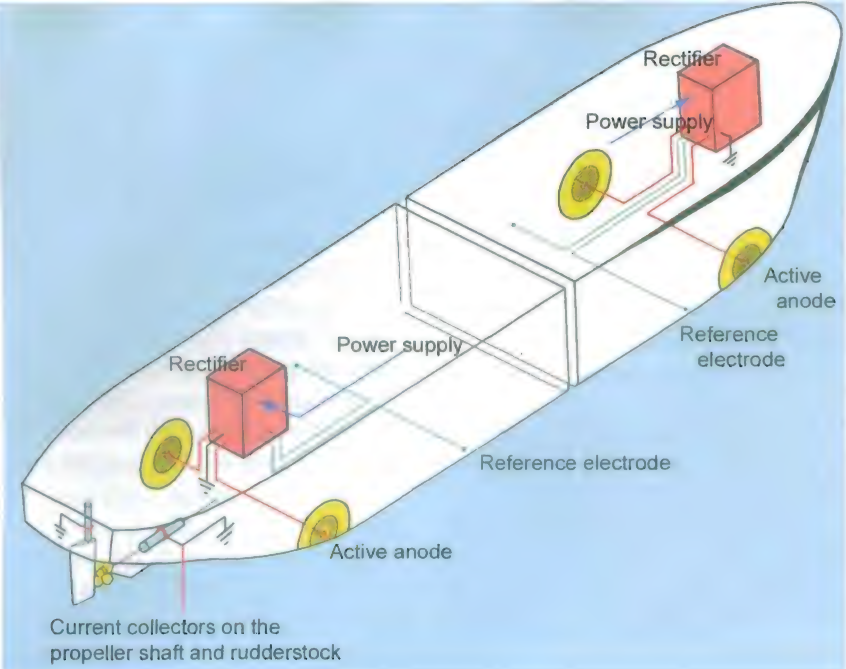
Anode in the shell

6.5 Impressed current

In the impressed current cathodic protection system (ICCP), a large positive current is applied to the hull and passed through the adjacent water. As a result, current flows into the ship's steel whereas it has a direct unprotected contact with the seawater inducing a cathodic reaction that protects the steel against corrosion. To achieve this, a rectifier is connected to the ship's steel with the negative exit. The positive exit is connected to two or more anodes in the ship's shell. These insulated anodes are embedded in the shell to prevent damage by floating ice and are made of inert materials (inert is another word for non-reactive).

Sometimes the very noble (but very expensive) metal platinum is used, but more often the anodes are made from a mixture of high-grade metal oxides (MMO, mixed metal oxides). Oxides cannot oxidate again. The selected oxides do not dissolve in water. If the anodic reaction has no metals to consume, the reaction will produce small bubbles of oxygen, which are not without harmful to the shell. The strength of the impressed current can range between 10 A and 600 A, the exact value depending on the size of the ship, the amount of damaged paint layer, the speed of the ship and the salinity of the seawater. The voltage can be as high as 20-30 V, depending on the number and positioning of the anodes. Where the shell is in direct contact with the seawater, this voltage reduces to 1.5-2.5 V.

Regulator



Principle of impressed current corrosion protection system

The ICCP-system has the following
Advantages:
- a minimum of maintenance is required
- high reliability
- action can be controlled at any moment
- an automatic regulator can adapt the current with the use of reference electrodes if a change in the water composition (fresh, brackish, salt) or damage to the paint layer requires this.
- the high investment costs (compared to a sacrificial system) will recover itself in approximately 6 years

Disadvantages:
- the costs of acquisition are significantly higher than those of a sacrificial system
- if the ICCP-system is incorrectly tuned it can cause extensive damage to the ship below the waterline
- some paint systems are damaged quickly when the ICCP-system is overprotecting (the current is too high)

Some remarks on cathodic protection and related matters:

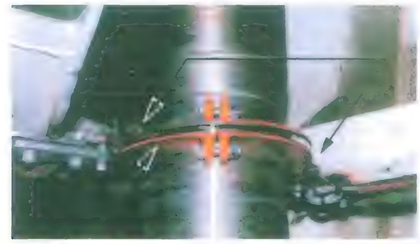
- ICCP-system is mostly used on ships with a length exceeding 40 meters
- Fast ships like patrol vessels and hydrofoil boats are always protected by the ICCP-system
- Aluminum ships cannot be protected passively
- In ships with a lubricated propeller shaft, the shafting should be equipped with a strong current collector. If this is not the case, the current will flow from the propeller to bearings or gear wheels of the engine or gear box. This can cause extensive damage.
  If the current collector is tuned incorrectly and the shafting has a faulty earthing, the gear wheels and the bearings can be damaged very quickly.
- The rudder stock has to be equipped with a good earthing if the rudder is to be part of the cathodic protection system
- Stainless steel, for instance in the propeller shaft, is protected against corrosion by a dense oxide layer called the neutralization layer. If this layer is damaged it will not fully restore itself. The new layer is not impermeable, so corrosion cannot be stopped. A wrongly tuned ICCP- installation can destroy the neutralisation layer of the stainless steel if it comes into contact with seawater. This does not happen in a lubricated propeller shafting.

7. Dry docking

7.1 Why dry docking?

- **The SOLAS Convention requires it.** (Chapter 1, Reg 10-V) This chapter states that every ship should be dry docked for inspection of the underwater parts at least twice every 5 years. The maximum time-lapse between two dry dockings should


Special paint layer around the anode


Earthing brush

not exceed three years. Only when special provisions have been made during construction, one of the dry dockings may be replaced by an in-water survey.
- Demanded by the bureau of classification. The demands from the Classification Societies are generally in compliance with SOLAS requirements.
- To repair damage below the waterline as a result of for instance:
  - collision
  - running aground
  - bad or no maintenance
  - propeller-shaft seal leakage
  - rudder damage
- Inspection when the ship is going to be sold.

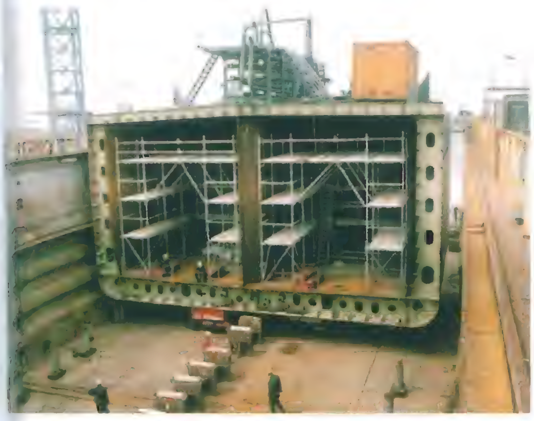
7.2 Methods of dry docking

- **floating dock**
- **excavated dock (graving dock)**
- **patent slip**
- **lift and subsequent horizontal transport of the ship**

Floating dock
A floating dock is, in fact, a pontoon with a vertical sponson on both sides in longitudinal direction. The pontoon and a part of each dockwall are divided into a number of tanks.

To dock, the following has to be done:
- the tanks are filled with water so the dock submerges sufficiently for the ship to safely enter it
- the ship navigates into the dock
- the tanks are emptied, the dock rises to the surface and the ship is lifted out of the water

Repair department of a dockyard with two floating docks



Tanker being built in a dry dock

Construction in an excavated dock

The front and/or the back of the sponsons are usually equipped with hingeable walkways to provide access to both sides. On top of the sponsons are found:

- pump control room
- traveling crane for handling, loading/onloading of parts
  capstans and bollards to control the ship's movements into the floating dock.

Electric motors are located in the upper part or dry room of the sponsons. These motors operate the ballast pumps that are located low in the tanks.

The manual controls of the inlet and outlet valves are also located in this compartment. Opening the inlet valves fills the tanks and lowers the dock. To raise the dock, the pumps are started and the outlet valves are opened.

The ship rests on the keel blocks that are placed on the tank top of the dock. These keel blocks are 1 - 1.25 meters apart and each can carry a weight of 100-200 tons, height 1.5 - 2 meters.

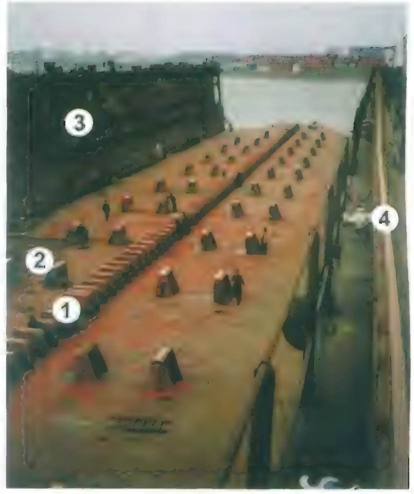
Side (bilge) blocks are used to keep the ship stable in the dock. They keep the ship in balance and are placed towards the turn of the bilge. All side blocks have to be placed in such a way that the forces they exert on the ship's hull are absorbed by the reinforcements present in the ship, like side girders and longitudinal bulkheads. The center line bulkheads and the web frames of the dock also have to be taken into account.

The positions of the blocks, the rise of bottom, the bottom tank drain plugs and other important data have to be indicated in the docking plan of the ship.

The rise of floor makes it necessary for the side blocks to have the correct height so that the weight of the ship is distributed over the keel and the side blocks. The dock master is responsible for the placing of the blocks as indicated in the docking plan of the ship.

Excavated dock

The excavated dock (graving dock) is closed using a caisson or door. The dock floor slightly slopes towards the opening. The pump room is also located near the opening. Most characteristics of the excavated dock are the same as those of a floating dock. The ship's trim is limited more than in a floating dock. The difference between the slope of the dock and the trim should not exceed 1 meter, to prevent high loads in the stern area of the ship.

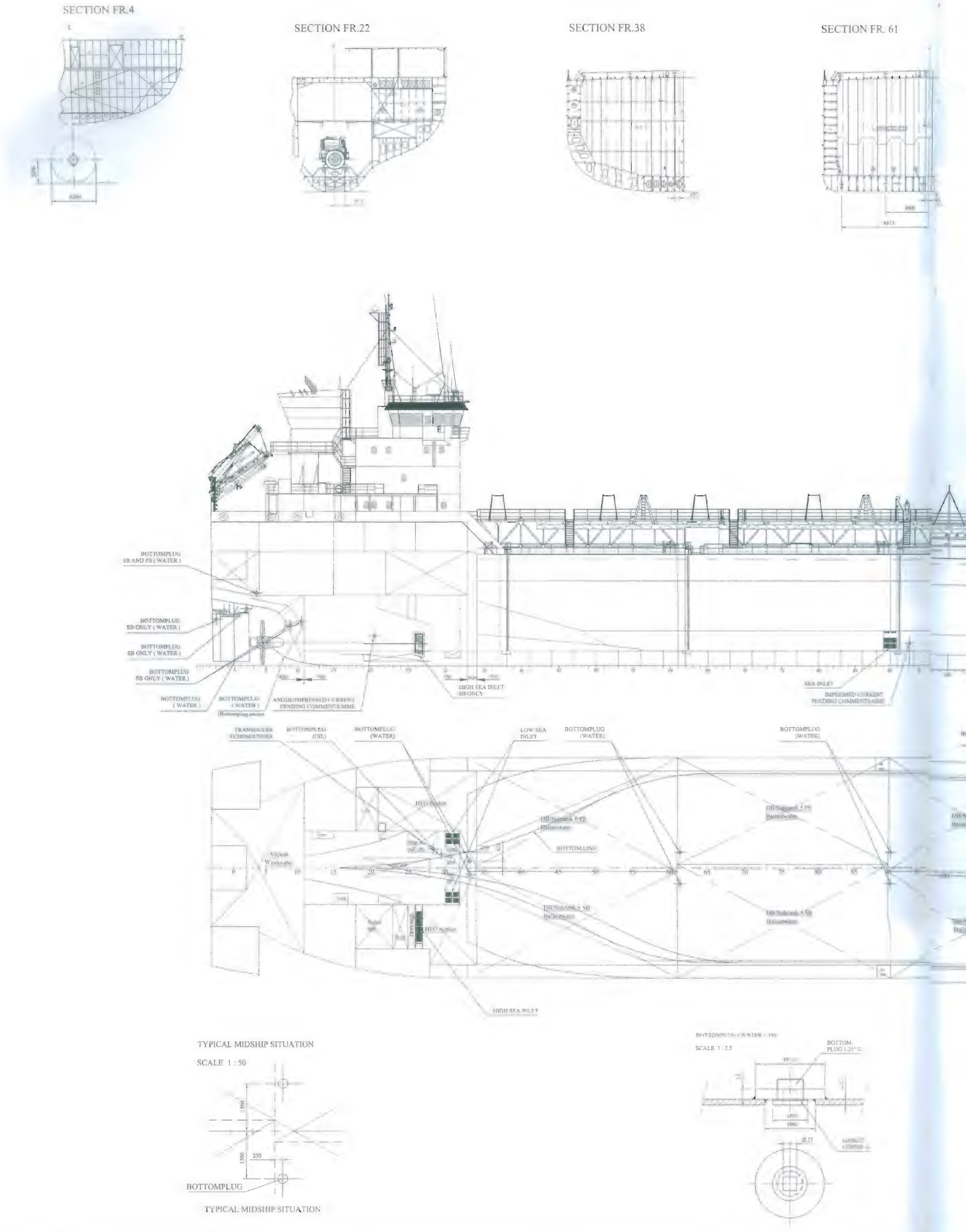


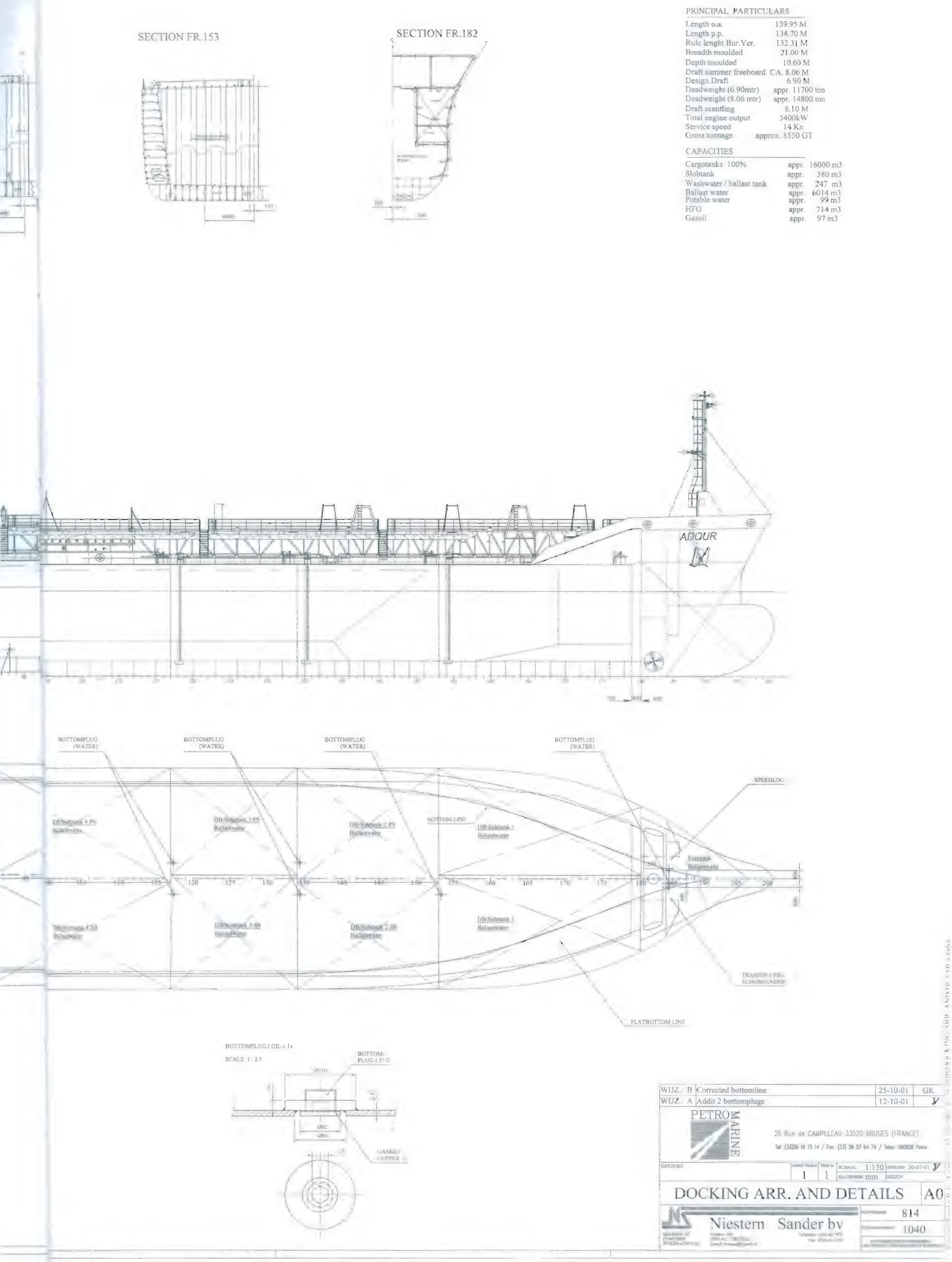
A floating dry dock. Data: length = 217 meters, width (internal) = 32 meters, draught above blocks = 7.5 meters, lifting capacity = 25,000 tons.

1. Keel blocks
2. Side blocks
3. Side sponson
4. Rails for the crane

A view under the ship in a dock (normal dock block arrangement)

Ship supported by special dock block arrangement with enlarged height (in a graving dock


SECTION FR.4
SECTION FR.22
SECTION FR.38
SECTION FR. 61
BOTTOMPLUG
SB AND PS (WATER)
BOTTOMPLUG
SB ONLY (WATER)
BOTTOMPLUG
SB ONLY (WATER)
BOTTOMPLUG
SB ONLY (WATER)
BOTTOMPLUG
(WATER)
BOTTOMPLUG
(WATER)
HIGH SEA INLET
SB ONLY
SEA INLET
TRANSDUCER
ECHOSOUNDER
BOTTOMPLUG
(OIL)
BOTTOMPLUG
(WATER)
LOW SEA
INLET
BOTTOMPLUG
(WATER)
BOTTOMPLUG
(WATER)
HFO Bunker
BOTTOM LINE
HFO Bunker
HIGH SEA INLET
TYPICAL MIDSHIP SITUATION
SCALE 1 : 50
250
1500
BOTTOMPLUG
TYPICAL MIDSHIP SITUATION



SECTION FR.153
SECTION FR.182
PRINCIPAL PARTICULARS
Length o.a. 139.95 M
Length p.p. 134.70 M
Rule lenght Bur.Ver. 132.31 M
Breadth moulded 21.00 M
Depth moulded 10.60 M
Draft summer freeboard CA. 8.06 M
Design Draft 6.90 M
Deadweight (6.90mtr) appr. 11700 ton
Deadweight (8.06 mtr) appr. 14800 ton
Draft scantling 8.10 M
Total engine output 5400kW
Service speed 14 Kn
Gross tonnage approx. 8550 GT
CAPACITIES
Cargotanks 100% appr. 16000 m3
Slobtank appr. 380 m3
Washwater / ballast tank appr. 247 m3
Ballast water appr. 6014 m3
Potable water appr. 99 m3
HFO appr. 714 m3
Gasoil appr. 97 m3
ADOUR
BOTTOMPLUG (WATER)
BOTTOMPLUG (WATER)
BOTTOMPLUG (WATER)
BOTTOMPLUG (WATER)
SPEEDLOG
BOTTOM LINE
TRANSDUCERS ECHOSOUNDER
FLATBOTTOM LINE
BOTTOMPLUG (OIL) 1x
SCALE 1 : 2.5
BOTTOM-PLUG 1.5" G
WIJZ.: B Corrected bottomline 25-10-01 GK
WIJZ.: A Addit 2 bottomplugs 12-10-01
PETRO MARINE
26 Rue de CAMPILLEAU 33520 BRUGES (FRANCE)
SCHAAL 1:150
mm
DOCKING ARR. AND DETAILS A0
814
1040
Niestern Sander bv

Patent slip
The patent slip lifts the ship in the transverse direction. Trolleys placed on rails roll into the water, until they are underneath the ship. If the trolleys are pulled back up again, they take the ship with them. The patent slip is used mostly for ships with a length of up to 140 meters. It is a fast and cheap method of making ships dry. Often more than one ship can be located on the slipway, and repaired or painted simultaneously. Common for ships for inland navigation.

Ship on a patent slip

Shiplift
A shiplift consists of one (or more) platform(s) that can be raised and lowered by a number of winch systems, located on both sides of the dock or on piers. Sometimes locking mechanisms are used to fix the platform at quay level and to take over the load from the winches.
Generally a shiplift system is used together with a transfer system, consisting of ship support beams (trestles or cradles), including wheel-bogies with hydraulic jacks.
To dry dock a ship, the transfer system (at least the trestles) is positioned on the lifting platform (at quay level), and the platform is lowered under water.
After the ship has navigated above the platform, this platform is raised by the winches, and thus the vessel is docked by hoisting it to quay level. Now the transfer system (complete with wheel-bogies) can move the ship horizontally to and over the dockyard, both in longitudinal and in transverse direction.
Winch systems are mostly electrically driven and may incorporate variable speed control as well as trim and list adjustments for the platform. Transfer systems generally include hydraulic systems for the vertical adjustment and the ideal "fluid bed" support of the vessel. Horizontal movement also comprises hydraulic drives.
Shiplifts nowadays exist for small ships (platform with 8 winches) up to ships of over 230 meter length, using 100 winch systems.

7.3 Preparing for dry docking

As mentioned before, the dock master has to determine the position of the ship and the side blocks in the dock in accordance with the dock plan. If possible, the ship should have no cargo on board. If there is still cargo on board, then docking can only take place in close consultation with the Classification. The structural integrity of the ship may require additional blocks to be placed. In case of a large ship, an extremely heavy ship, or a ship with an abnormal shape, a proposal for the block positions is made and submitted for approval to the Owner's representative and if applicable to the Classification.
Every dry dock has its own block pattern and this has to be adapted as far as practicable to the ship's construction. In such cases the blocking preparation is controlled and measured prior to the actual dry docking.

The ship should enter the dock preferably on even keel. A floating dock can be positioned with the same trim as the ship. The maximum allowable trim of the dock differs per dock.

7.4 Dry docking

Once the ship has entered the dock, the dock master is responsible for the dry docking. The ship must be moved exactly above the centerline row, before the dock is pumped dry. The ship is positioned correctly by dock winches attached to the fore and aft, both on port and starboard side. The dock master gives the orders to the operators of the winches. The exact middle of the dock is indicated by a cable and a plumb line, which are suspended between the two sides. Another method is to use a measuring rule to determine the distance between the edges of the dock and both the ship's sides forward and aft. The ship will touch the docking blocks when

Shiplift, with, after being lifted to platform level, horizontal transport of the ship on trolleys and rails, in two directions: first forward, afterwards sideways. One lift-system can have many ships dry at the same time

Shiplift

Shiplift

the draft of the side sponsons equals the ship's draft. The draft of the sponsons is the draft above the keel blocks. The ship has **'bit'** when it touches the docking blocks.

The **stability** of the ship will decrease if the weight exerted by the ship on the dock blocks increases. The apparent rise of center of gravity 'G' is faster than the rise of the metacenter

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Side launching, or transverse launching.

'M', in other words: G catches up with M. Bilge or side holders have to be placed before the stability becomes zero (GM=0).

A critical moment for the floating dock arises when during the last phase of coming dry, several decimeters of water, still present on the dock floor, start to move. A large area of free floating fluid can come into motion. Before the dock is dry, all water cooled engines and auxiliaries on the ship have to be shut down. If the ship has air cooled auxiliaries, these can keep supplying the ship with power. If these are not present, electricity from the shore must be utilized. A requirement of the shipyard is that the ship is connected to the shore based fire-fighting installation by means of hoses connected to the onboard international shore connection.

7.5 Refloating

Before the dock is submerged to undock the ship, the presence of all the plugs, grills, anodes, inlet and outlet valves, manhole covers etc. has to be checked.

The ship should leave the dock, if possible, in the same ballast condition as when it entered. This means that ballast tanks, if emptied to prevent condensation of the ship's shell, have to be refilled using the dock pumps, over the top (a different, also suitable ballast condition can, of course, be calculated). When the ship is floating again, the engine room compartment and bilge wells have to be checked to determine if there is any leakage. Repairs to double bottom tanks and side shell must be tested prior to undocking.

8. Maintenance, Repairs and Conversions

Ship maintenance is usually divided into hull and engine maintenance.
Hull maintenance is normally done in dry dock. A ship has to be dry docked twice every five years. This is basically for examination of the underwater parts by Class. When no repairs are to be carried out, it means only examination, cleaning and repainting of the ship's outside hull. Maintenance of decks, and everything inside the hull is usually done by the ship's crew.
When the ship is high and dry in dry dock, the outside of the hull is cleaned using high-pressure water jets, to remove dirt and fouling, and to make the hull ready for repainting. Oily spots, if any, are removed with special solvents. Rusty spots are specially cleaned using sand-discs, gritblasting, hydro (water) blasting, as cleaning method. The original paint system of these spots is to be restored, after which the entire outside hull can be painted as wished by the owner. Sometimes, when the roughness of the underwater hull has become too high, due to numerous layers of paint and local touch-ups, the entire underwater part is blasted to remove all the rust and paint, and to start the paint system as new. The paint supplier gives advice, and keeps control of cleaning and paint application. Depending on the age of the ship, size, speed, cost and the requirements of the trade, the paint system is chosen, from simply one coat of tar to more expensive systems as vinyl, chlorinated rubber, epoxy or polyurethane undercoats followed by various coats of sophisticated antifoulings.
After drying and cleaning, the vessel has to be examined in dry dock by the Classification surveyor, normally accompanied by a representative of the owner and the shipyard in order to investigate the condition of the underwater parts. No defects underwater are to be neglected, to prevent unforeseen repairs during operational time. Emphasis shall be put on rudder and propeller, tail shaft, indents, damage, paint-condition, corrosion, fractures, weldings, and inlet and outlet pipe stubs. Defects affecting Class are to be dealt with. Minor defects not requested to be repaired by Class, can be left as are, as per owner's choice.

To get the Docking Survey credited for Class, the following underwater parts of the hull have to be examined:
- Tail shaft and propeller
- The tail shaft seal
  The rudder and rudder stock
- Propeller shaft wear down
- Clearance of rudder bearings have to be measured
- Sea-inlet boxes are to be opened up, cleaned and painted internally. It is mostly the same procedure as for the outside hull
- Anchors and chain cables.

If all is in order or dealt with, the legal part is dealt with.
The tail shaft and propeller have to be examined and the tail shaft wear down measured.

The old paint-layer is removed by gritblasting

Classification Surveyor, writing his comment on the object

This gives information about the condition of the stern-bush bearing. Standard every five years, the **tail shaft** has to be withdrawn, to examine the shaft, and to examine the stern-bush bearing. The propeller is then suspended using special tools from the yard. Simultaneously the **tail shaft seal** is opened up and overhauled.

Controllable-pitch propeller shafts and keyless propeller shafts do not need to be withdrawn at five year intervals, they can be left for a longer time.

When the clearance of **rudder bearings** has become too big, the rudder has to be lifted out of the pintles, and the relevant bearings have to be renewed. The larger the ship, the heavier the rudder. For a VLCC (Very Large Crude Carrier) the rudder weight can be 100 tons or more. Rudder posts, which often are lifted for access to the rudder, follow the same pattern. Special lifting gear must be available at the yard.

Anchors and chain cables are lowered. Blasting and painting in progress.

Preparing propeller and tail shaft for proper fit on tapered end of the propeller shaft prior to installation on board

Anchors and **chain cables** are lowered and laid out, and measured up, to establish any loss of thickness due to corrosion and/or wear. When they fall below requirements, the chains are to be replaced. Inspection of anchors and chains and their measurements are required at least every five years. When the anchors and chains are lying in the dry dock, it is customary to clean the chain lockers, which themselves have to be examined for class and Special Survey. Another standard item of the dry dock repair list is opening and overhaul of sea-inlet and overboard valves. They need cleaning, inspection, disc-grinding of seats and repacking of stem-glands at least once in five years.

Exchange of crank shaft

Rudder condition when vessel just dry in dry dock. Access plates of rudder-pintle-nuts missing(lost) and rudder itself heavily fouled.

The same rudder after cleaning, painting and fitting of new access plates. Often there is no time left for rudder painting, as in that area there is always much work to do in dry dock, to rudder and propeller, and the workers do not like fresh anti-fouling paint.

Most of the engine maintenance is done while the ship is in operation, partly during voyage. Items which only can be done when the ship is not underway are done in port.

The Classification Societies request the ship owner to show to them each surveyable item once every five years. **Surveyable items** are engine parts or systems essential for the safe navigation of the vessel and are listed on board and ashore. This survey can be done at the end of the five year Special Survey cycle, or on a continuous basis during the whole period.

Under certain circumstances part of the surveys can be done by the ship's chief engineer when he or she is specially qualified. Details have to be submitted of what was seen and done. Some engine parts need more attention than once in five years: coolers, pistons, turbo-chargers, etc. Maintenance of items which are too large or too difficult, or which simply cannot be done afloat, is done at a shipyard. This is usually not a new building yard, but a specialized repair yard.

8.2 Repairs

Repair yards have equipment totally different from new building yards. Their dry docks are deeper because a ship in operation is heavier and has consequently more draft than an empty newly built hull. Also cranes do not need to have the lifting capacity of those in a new building yard. They need height, more than lifting capacity.

The workshops are equipped differently: other machines, for small and sometimes big repair work. The workers need to have different skills from new-builders and have to be more flexible and more used to changes. Also the locations of repair yards are often different from the newbuilding yards. To minimize deviation from the normal trade, they are found in the big loading and discharge ports or en route between common discharge and loading ports, especially for large tankers and bulk carriers.

Damaged bow

A new bow

The bow brought in position.

The new bow is attached

Repair yards are used to performing normal maintenance work, but must also have the flexibility to carry out repairs. When during the dry dock inspection a problem is observed, there has to be capacity to deal with this immediately. Therefore, repair yards need to have more than one dry dock for similar ships, and are often specialized for certain sizes and types of ships.

Typical repairs are related to certain ship types. Bulk carriers always have work to be done to hatch covers, crude tankers to pipelines in the tanks and pump room and to valves, hopper dredgers to bottom-flaps, container ships to container guides, etc.

A repair yard always has shops and/or departments for hull, machinery, pipe repairs, electrical repairs, woodwork, and cleaning and painting. Often specific and/or specialist jobs are subcontracted to separate companies.
Common repairs to hulls are steel renewals, in dry dock and afloat, such as repairs of an indent caused by a collision with a jetty, steel renewals resulting from grab discharge, local corrosion or from grounding. Grounding damage can vary in size from a small indent to a whole flat bottom. Fire damage also often involves steel repairs.

Shape

Repairs to shell plating often come with the problem of **shape.** Nearly all ships have different forms, and when a hull plate is not in the flat bottom or ship's side, the curved shape has to be restored. When the new building offsets (tables measured from the original new building mold), are available, the relevant part of the hull can be drawn up on a moldloft, and the shape can easily be established from this real-size drawing. Or, when the damage is on the portside, measurements are to be taken on the starboard side.

8.3 Computerized Shape Technics

When there is damage to the ship, usually below the waterline, the ship has to dock at a repair yard to survey the damage. After the survey, the parts that have to be replaced can be fabricated, e.g. the shell plating with the stiffenings and other strengthening parts. Then they can be installed. The most time-consuming factor is the retracing of the original form of the hull, which can cause a relatively long period in dock.

Modern laser techniques can shorten the time needed to measure the shape. By measuring a number of spots on one side, at known coordinates, the shape can be calculated for the other side, this making a full size drawing of the lines not necessary.

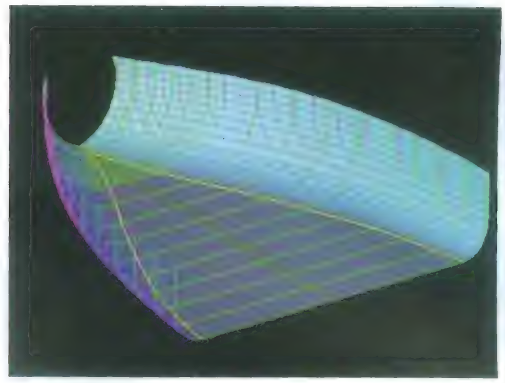
When the yard uses a modern, 3D CAD/CAM computer program this process can be done computer-aided. More and more of these programs are used by modern shipyards. Shortly after the damage has occurred, the extent of the damage can be investigated and upon inspection by the surveyor, insurance party and the owner, the extent of repairs will be agreed upon. Then the preparations can be started up by the selected repair yard, preferably by preparing prefabricated sections on the basis of the CAD/CAM program if available.

Depending on the extent of the damage the ship can proceed on its voyage and the lay time can be reduced as far as possible. Only when the sections that have to be replaced are fully constructed, will the ship have to go to a dry dock for repairs. This way the sailing time lost is as little as possible, which is the primary goal for the ship owner.

In repair yards the use of these programs is not widespread, whereas in new building it is quite common.

Bottom damage

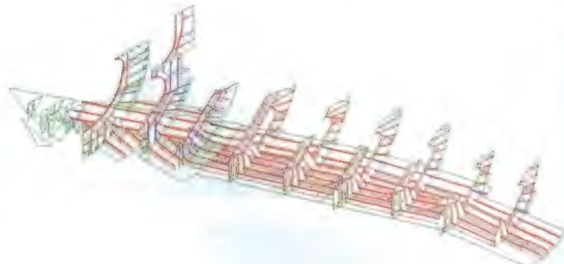
Part cut out



Ship's shape in Tribon Lines

New part lowered...

..and brought in position to be attached



8.4 Conversion

Related to ship repairs, more than to new building, is the process of ship conversions. Existing ships are sometimes modified into something totally different from the original ship. Bulk carriers are converted into drill ships or into pipe layers; tankers are getting a second life as FPSO's (Floating Production and Storage Offloading) cargo-ships, Ro-Ro ships or tankers are simply lengthened, an existing aft ship with engine room is coupled to a completely new fore body; original steam propulsion is changed to diesel propulsion; passenger ships are upgraded with more cabins, from emigrant transport into cruise ship, or from ferry into floating hospital, etc.

A special field is work related to **offshore** oil and gas exploration and production. Due to the continuous change in requirements for certain jobs, drilling units, storage systems, or transport barges often have to be modified before they can carry out the next job. This kind of work is also normally done at a repair yard.

Sometimes they use new building capacity to make the new parts, for instance, to have a new mid-body built in case of a lengthening.

A passenger ship is being lengthened to increase capacity.

CHAPTER 15

Safety

1. General

1.1 General

Safety on board ships is an important issue. Normally at sea and often very far from any possible assistance, there is nobody who can be called upon for help. Of course, the ship should be of good design, well maintained in seaworthy condition with sufficient stability, watertight and weather tight and properly equipped. However, safety on a ship is not guaranteed by availability on board of the (compulsory) safety items and systems. Safety cannot be bought. Most of the accidents on board ships are the result of human error.

Prevention through recognition, rectification and avoidance of unsafe actions and/or situations at all times and at all places on board by all personnel is of utmost importance.

Training in how to walk and climb while using a BA-set (breathing apparatus)

Since July 2002, all ships (and their ashore offices) have to be certified under the **International Safety Management** Code (ISM Code) and the crew has to work in accordance with the **Safety Management System** (SMS). The SMS is a set of rules, describing in detail how to apply safety in general and how to use safety gear.

Courses and regular drills are held in order to ensure that the crew is safety-conscious. The crew is trained to use the right equipment in case of an accident. In a crisis situation people are not logical thinkers. They tend to act instinctively using the things they learned during the courses and drills. When situations have not been addressed and the crew are unfamiliar with the situation they tend to panic. In case of fire, especially on tankers, inadequately trained people have jumped overboard, often with fatal consequences.

Chapter I:	General provisions
Chapter II-1:	Construction - Structure, subdivision and stability, machinery and electrical installations
Chapter II-2:	Construction - Fire protection, fire detection and fire extinction
Chapter III:	Life-saving appliances and arrangements
Chapter IV:	Radio communications
Chapter V:	Safety of navigation
Chapter VI:	Carriage of cargoes
Chapter VII:	Carriage of dangerous goods
Chapter VIII:	Nuclear ships
Chapter IX:	Management of the safe operation of ships
Chapter X:	Safety measures for high-speed craft
Chapter XI:	Special measures to enhance maritime safety
Chapter XII:	Additional measures for bulk carriers
Appendix:	Certificates

An overview of the index of SOLAS

1.2 Regulations

Regulations concerning safety on ships are formulated by the IMO department called the **Marine Safety Committee** (MSC), responsible for the **SOLAS-Convention**. The sub-committee on Standards of Training, Certification and Watchkeeping (STCW), have regulated the certification of seafarers in the STCW Convention,

The SOLAS Regulations apply to all ships over 150 GT for radio and over 500 GT for radio and safety equipment. Ratification by the relevant flag states means that they will adopt the regulations in their national laws.

2 Fire protection, fire detection and fire extinction

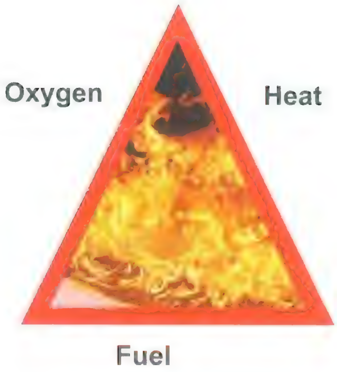
2.1 Purpose

The most important issue of course, is protection. Protection through construction is, as said above, addressed in Chapter II-1. It prescribes the positions of bulkheads, materials for subdividing structures, in combination with the use of non-flammable materials, fire-proof doors, fire-proof insulation etc. The three elements for combustion are: **flammable material, heat and oxygen,** which should not be allowed to combine and create fire.

2.2 Combustion process

Combustion is a chemical reaction caused when a flammable compound reacts with oxygen. This compound form a chemical bond with oxygen under the release of heat and the formation of new compounds. This process is known as oxidation. Combustion is happening everywhere unnoticed, for example in the human body or in corrosion, such as the rusting of iron.

An actual fire will only occur in the presence of a combination of all of these factors. If one of these factors is removed, there will be no fire and if there already is a fire, it will be extinguished. Fire prevention and fire fighting are based on this principle. The necessary factors are shown in



The fire triangle

the fire triangle. If just one side of the triangle is taken out of the equation, then the fire will cease.

The ignition

The heat that is necessary to start the fire must possess certain elements-ments. For a solid or a liquid to ignite there has to be some vapor or a gaseous product. This is the case when the compound is heated until enough vapors and gases have been generated to form a flammable mixture.

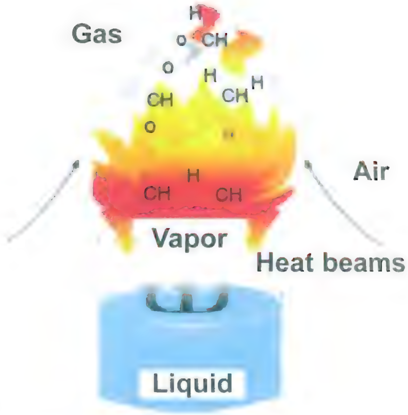
To ignite a liquid, there has to be gas above the liquid. The liquid itself cannot burn, though the gas can, when there is oxygen and the temperature is sufficiently high.

The lowest temperature at which this situation occurs is called the **flash-point.**

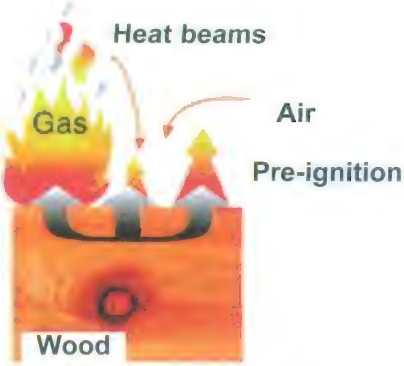
However, it is possible that when the flashpoint is reached, the combustion will cease after ignition. The reason for this is an incomplete mixing of gas and air. The lowest temperature at which combustion will continue after ignition is called the **ignition temperature**.

At this temperature, enough vapor is formed to sustain combustion; the heat is in equilibrium. To sustain combustion after ignition a sufficient amount of heat has to be released. This is the case when more heat is produced than can be absorbed by the surroundings.

Combustion is also possible without ignition from outside. If enough heat is pumped into the fuel, the temperature may become so high that it will ignite spontaneously. The lowest temperature at which this can occur is called the (spontaneous) **combustion temperature**.



Combustion of a liquid



Ignition and combustion of a solid

The fire pentacle

From the preceding section, it is apparent that the fire triangle alone does not suffice; the oxygen/fuel ratio is also very important in the ignition and sustaining of a fire.

Additionally, a fire cannot start without a catalyst.

If there is no catalyst in the vicinity of the fuel then (over-)heating can still start the combustion process because the fuel will form its own catalyst.

The general catalyst in combustion is water vapor, present in the atmosphere.

If the two factors oxygen/fuel ratio and catalyst are added to the fire triangle a fire pentacle is formed.

The fire pentacle

A catalyst is a compound that accelerates a chemical process without being consumed.

An everyday example of this is the combustion of a sugar cube. You can not light a sugar cube with a match or lighter. However, when you put some ash on the cube, you will be able to set fire to the sugar. The ash is working as a catalyst. In essence, a catalyst reduces the energy needed for a process in comparison with the process in the absence of the catalyst

Fire classes

Fire classes highlight the characteristics of combustion depending on the type of fuel. The fire class is used to determine which method of fire-fighting is most suitable for the particular fuel.

Class of flammable goods

A	Solids	Wood, paper, textile, plastics
B	Liquids	Liquefying goods, petrol, alcohol, stearine, fat, tar, paint
C	Gases	LPG, butane, propane
D	Metals	Magnesium, aluminum, titanium, zirconium, sodium, potassium

Overview of fire classes and the types of fuels

2.3 Fire-fighting

When there is a fire, all attempts must be made to extinguish it.
There are various means of fire-fighting, such as removing:
- heat, (2.3.1)
- oxygen (2.3.2)
- flammable material

2.3.1 Removal of heat

This can be done by:
a. **Solid Water.** When the water evaporates from the heat of the fire, this takes a large quantity of energy from the fire. When there is sufficient evaporation, the fire will die.
b. **Foam.** Foam is a mixture of water with foam-making liquid. The process and result is the same as above.
c. **Mist**. Mist consist of very fine droplets of water. The result is the same as a.
d. **CO_2**. When released into a closed space, it will form a mist. The droplets need to become gas, and this process uses heat. (This is a side effect of extinguishing fire with CO_2)

2.3.2 Removal oxygen

Without oxygen a fire cannot continue. The percentage of Oxygen can be reduced by adding another gas without oxygen.

a. **CO_2**. Releasing CO_2 into a closed space, pushes the air, depending on the quantity of CO_2, out. When the oxygen is below 8 percent, a fire can not normally exist.
b. **FM 200**. Same as above.
c. **Close the space** completely where the fire is. The oxygen present will be used untill the percentage is too low to maintain a fire.

2.3.3 Removal of flammable material

Close a valve in a pipeline where oil emerges onto a very hot surface, deprives the fire of its fuel.

2.4 Fire-fighting Means

2.4.1 Portable fire extinguishers

The first line of defense on board is usually the portable fire extinguisher (dry-powder, CO_2 or foam).
Dry-powder extinguishers, usually with 6 kg powder, are placed in the accommodation and other easily accessible spaces. The engine room must contain a 20 kg unit, and tankers must have them in the manifold, during loading and discharge operations. The powder is suitable for three categories of fire:
A in solids
B liquids
C gases-

Cross-section of a powder extinguisher

Cross-section of CO_2-extinguisher

1. Carrying handle
2. Control lever
3. Outlet pipe
4. Snow horn
5. Blow-out pipe

Usually extinguishers are filled with a mixture of the three powders, making them versatile. The extinguisher consists of a closed container with powder and a compressed gas (carbon dioxide) cartridge. A pin opens the cartridge when hit, bringing the container under pressure and blowing the powder out.
CO_2 portable extinguishers are used in case of electrical fires in a switchboard and oil fires, for instance, in the uptake of a galley.

Portable foam extinguishers are used in engine rooms, but are increasingly being replaced by powder extinguishers.

Foam trolley

Spare charges for the extinguishers or a sufficient supply of all types of fire extinguisher are required to be stored on board.

When a fire is too big to be dealt with by portable extinguishers larger capacity systems are available.

2.4.2 Water

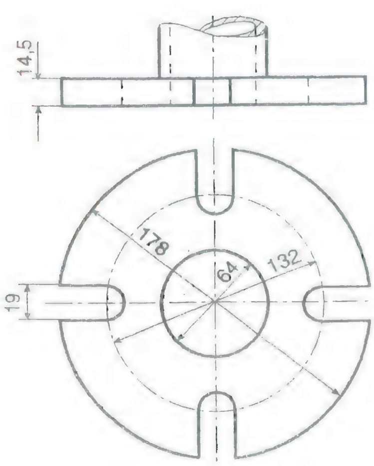
a. Main fire line system and hoses

The most versatile, easiest and cheapest medium available for extinguishing a fire.

Therefore, ships are provided with:
- fire pumps
- pipe-line system for water under pressure to reach every location on a ship
- hydrants at regular distances
- hoses

When hoses are connected to the appropriate **hydrants** all parts of the ship can be reached.
The pipe-line system must be supplied by two fire pumps, situated in the engine room, each having sufficient capacity and pressure for the whole system.
An **emergency fire pump**, individually driven, is located in a separate fireproof compartment. This pump has sufficient output to supply two hoses.

Near each hydrant a hose must be stored, fitted with a dual-purpose nozzle for a solid jet and for spray. The hydrants and the hoses are provided with fast-fit standard connections. (There are three systems - Snap-on, Storz, London Fire-Brigade).
In order to be assisted by the shore fire-brigade, in port, an **International Shore Connection,** a standardised piece of pipe, to which the local fire-brigade can connect their water supply to pressurize the ship's fire main, has to be present.



The International Shore Connection for the fire line. (SOLAS requirement)

Disadvantages of fire-fighting using water:
- ship stability can be endangered due to large quantities of water
- water itself can also result in damage
- water is not suitable for all fires

b. Fixed pressure water spraying system

Various systems have been developed to spray water in or over areas, which are vulnerable in case of fire, such as public spaces in passenger ships.

- **Drenching**

Ro-Ro vessels have **open sprinklers** throughout their car decks, operated from a central fire-control room. When a fire alarm comes in, the fire is located by the related alarm head, and after inspection, by an officer or via closed circuit TV; the valve of the relevant area of the car deck can be opened manually. The capacity is much higher that of ordinary sprinkler systems. The cargo, trucks, trailers and vehicles are much more dangerous than a cabin. **Deck scuppers** must have the capacity to cope with the water quantity so as not to cause loss of stability due to the free surface effect of the water. This system is also called a Deluge system.

- **Sprinklers**

In each cabin, depending on its area, one or more sprinkler heads are fitted in the deck head. These sprinkler heads are connected to a pipeline supplied by a pressurized vessel filled with water. A glass crystal closes the pipe. When heat is develops in the space, the glass crystal breaks, water flows out and is diverted by a rosette into an umbrella shaped water fountain. When the pressure in the water vessel drops, a pressostat starts a fire pump, providing the vessel with water, to keep the flow going. The pressostat also triggers the fire alarm.

*Sprinkler with heat detector. If a rise in temperature causes the red liquid to expand, it will break the glass and shoot down the nozzle. Subsequently, the water is driven out in the form of mist.
The color of the liquid indicates the working temperature, for example 68 °C*

Fire on the fore ship of a large crude tanker. Foam has been used in an effort to extinguish the fire

c. Foam

Water can be mixed with chemicals, so that when expelled through a nozzle where it can be mixed with air, foam is developed. There are three systems:

- high-expansion foam,
- pre-mix ordinary foam and
- foam made in a **proportionator**.

The foam-forming chemical is normally ox-blood or an artificial equivalent. The mixing rate is 3 - 6%.
Both low and high expansion foam can be used in spaces like engine rooms. It can fill the whole space through a system of nozzles, strategically placed, without doing much harm to the equipment. The water is the coolant.

Ordinary foam, pre-mix or mixed with water is applied via a proportionator, which is a venturi tube.
The foam liquid is injected into the narrow part of the tube. This is used on tankers to lay a blanket over the deck. It separates a fire from the air, and thus from oxygen. Foam in small quantities can be used via Foam Applicators, usually available in an engine room. The applicator is a small drum with foam liquid, connected to the throat of a venturi tube which is connected to a fire hose. When spraying water, the foam liquid is sucked up and mixed with the water, producing foam.

d. Fog

A relatively new development is water fog. Fresh water is pressurized through very fine nozzles so that the water comes out as a fog. Whereas sprinklers splash everything from above with water, the fog fills the entire space with a cloud, even underneath furniture, etc.

Since 2002 the 'local water mist system' is compulsory on new ships larger than 2000 GT and an engine room larger than 500 m^3. As of 2005, the system has to be available in existing passenger ships as well.

This system is a means of extinguishing that falls between a manual extinguisher and a 'total flooding system', like CO_2. It has to be fitted near equipment which are at great risk of fire, such as the main and auxiliary engines, boilers, separators, etc. Each section is separately operable and protected by smoke and flame detectors.
When one detector detects smoke or flame, an alarm is activated. When a second detector detects, the system activates. The control unit opens the valve of the section, starts the fire mist pump, and the equipment is enclosed in water mist emitted from special nozzles.

The system can be activated in three ways:

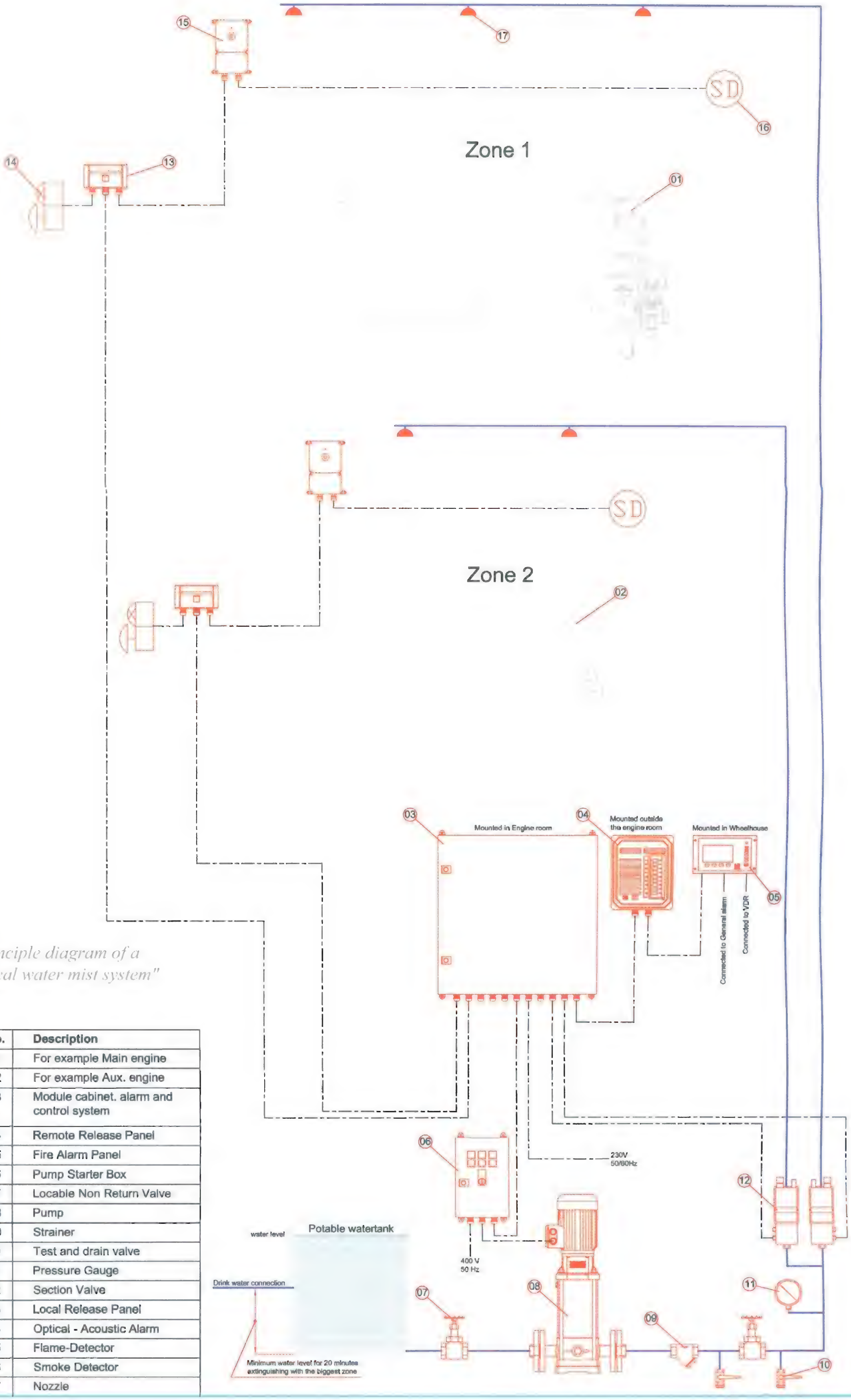
- Automatically,
- Manually - locally by a push-button
- Remotely - from a panel outside the engine room

Advantages:

- minimal water damage
- "large water area" making fog very effective in causing more heat extraction
- oxygen depletion by steam forming
- repetitive action

Disadvantages

- high capital cost compared to that of CO_2
- bilge system necessary to discharge water
- water could cause some additional damage



Principle diagram of a "local water mist system"

No.	Description
01	For example Main engine
02	For example Aux. engine
03	Module cabinet, alarm and control system
04	Remote Release Panel
05	Fire Alarm Panel
06	Pump Starter Box
07	Locable Non Return Valve
08	Pump
09	Strainer
10	Test and drain valve
11	Pressure Gauge
12	Section Valve
13	Local Release Panel
14	Optical - Acoustic Alarm
15	Flame-Detector
16	Smoke Detector
17	Nozzle

2.4.3 Fixed gas systems

a. CO_2 (Carbon dioxide)

Fixed gas fire systems fill a space with a gas that reduces the oxygen content or is an anti-catalyst that will extinguishes fire. It reduces the oxygen content to a level at which fire cannot exist. Such a system can only be used in closed compartments.

Carbon dioxide, although very effective, is very dangerous to people. A large number of fatal accidents has necessitated the search for less harmful alternatives. For a number of years **Halon** was used, but being a CFK, was abandoned due to environmental concerns. There are a number of Halon replacements, but these are so expensive that CO_2 is usually installed in new buildings, as well as engine rooms and cargo holds.

The system consists of a battery of bottles of CO_2 under high pressure (200 bar), creating an atmosphere with insufficient oxygen to allow combustion when discharged.

The bottles for a cargo hold are part of the engine room's equipment.
The content of the bottles have to be checked yearly, by weighing or by a level check using a radio-active isotope.

Advantages of CO_2

- no consequential damage
- transport over long distances through pipelines possible
- a relatively low cost material

Disadvantages:

- High risk for personnel
- High quantity of gas needed
- Cylinders have to be stored in an isolated space, outside the protected space
- Many safety devices needed
- The action is not repeatable

VOL% CO_2	Symptoms after breathing CO_2
0.03	normal CO_2-concentration
0.5	TLV and MAC-value
1.8	Increase in lung ventilation by 50% (hyperventilation)
2.5	Increase in lung ventilation by 100%
3	Light stupefaction, less accurate hearing, faster heartbeat and higher blood pressure
4	Increase in ventilation by 300%, heartbeat and blood pressure
5	Symptoms of poisoning after 30 minutes; headaches, dizziness, transpiration
8	Dizziness, stunning and unconsciousness
9	Breathing difficulty, drop in arterial blood pressure, congestion, death within 4 hours
10	Disorientation and dizziness
12	Immediate unconsciousness, death within minutes
20	Narcosis, immediate unconsciousness, death by suffocation

TLV = Threshold Limit Value
MAC = Maximum Allowable Concentration
Congestion = accumulation of blood

Admission

Before CO_2 gas can be released, various safety measures have to be taken including:

- **a head count** to ensure that no people are left in the engine room
- all openings to open air have to be closed, usually manually

CO_2 can be released from more than one position:

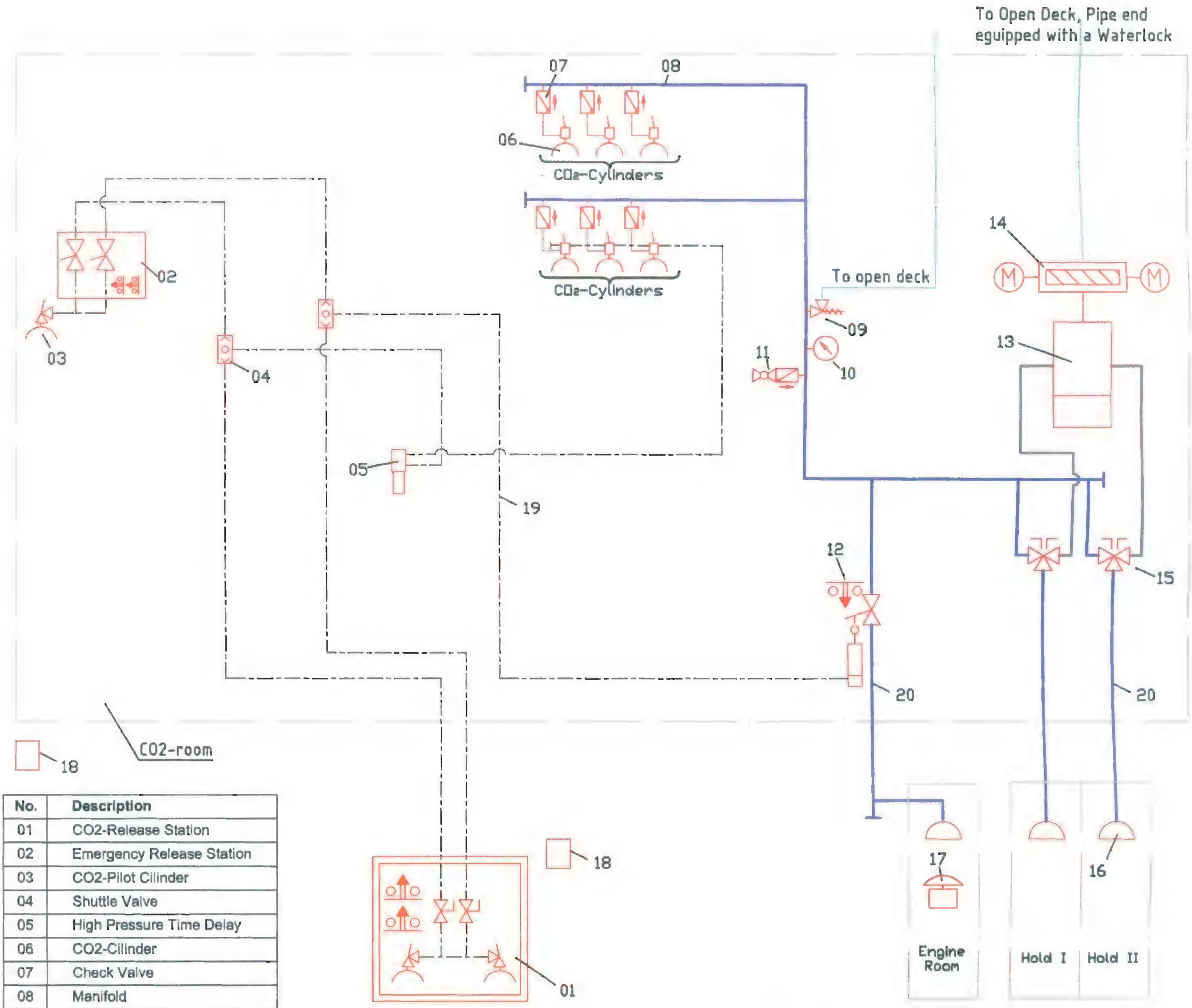
- from the CO_2 room
- remotely from a cabinet somewhere else in the accommodation preferably in a special safety room or on small ships, outside, and on larger ships, from the fire-fighting control room.

When the door of the locked cabinet with the release system is opened, the CO_2 alarm is triggered, and **claxons and flashing lights** are started in the engine room. By opening the door of the cabinet, all ventilation stops automatically.

In all locations, the vital release valves are inside a locked cabinet.The valves on the various oil tanks in the engine room can be closed as well, stopping all oil flow towards machinery. There are also remote stops for all oil pumps in the engine room.

CO_2 release to a cargo hold has to be done in the CO_2 room, as only part of the battery is involved, and the bottles have to be selected manually by fitting pins.

Entrance CO_2 room

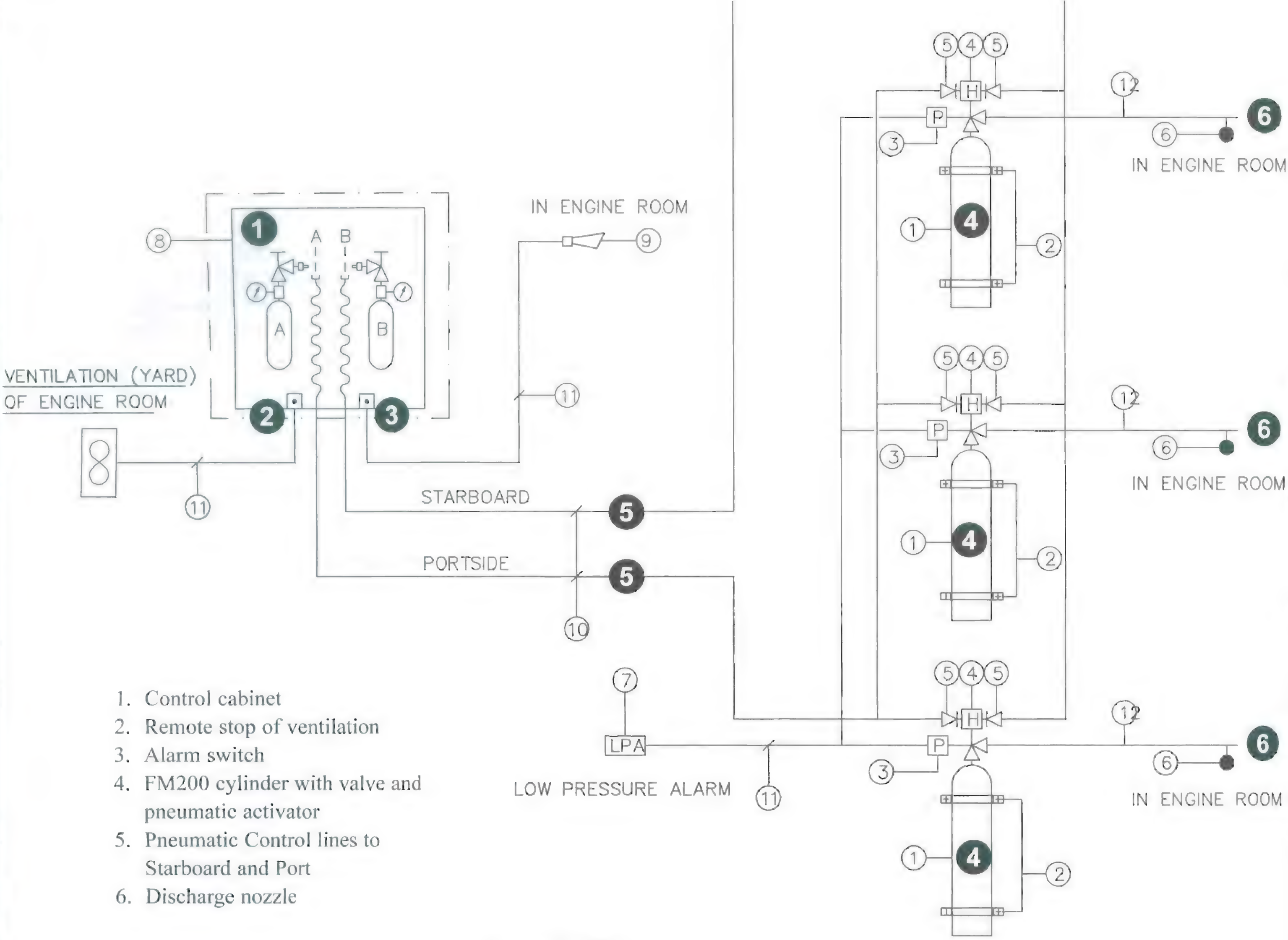


No.	Description
01	CO2-Release Station
02	Emergency Release Station
03	CO2-Pilot Cilinder
04	Shuttle Valve
05	High Pressure Time Delay
06	CO2-Cilinder
07	Check Valve
08	Manifold
09	Safety Valve
10	Pressure Gauge
11	Shore Connection
12	Section Valve
13	Smoke Detecting Cabinet
14	Fan Unit
15	Ball valve 3/2-ways
16	CO2- Nozzle
17	Acoustic alarm sounder
18	Key Box
19	Pilot Piping
20	Distribution Piping

CO_2 total flooding system

Main hand-operated valves to release CO_2 to the cargo holds.

CO_2 -cylinders



1. Control cabinet
2. Remote stop of ventilation
3. Alarm switch
4. FM200 cylinder with valve and pneumatic activator
5. Pneumatic Control lines to Starboard and Port
6. Discharge nozzle

Scheme FM 200

b. FM 200 (HCFC = hydrochloro fluor carbons)

FM200 is used on smaller ships with an engine room smaller than 450 m³. In larger engine rooms CO_2 is more attractive from an economic standpoint.

FM200-gas is a chemical composition. In contrast to HALON there is no break-down of ozone, but it still contributes to global warming (as does CO_2).

FM200 is stored as a liquid, under low pressure and Nitrogen padding. Pressure 25 to 42 bar at 20 °C. The fire extinguishing is based on cooling; the temperature is brought down to below flame point. A side effect is oxygen depletion.

Only 8.7 % of the engine room net content needs to be released, based on a release time of 10 seconds.

Advantages:
- not harmful to personnel in the afore-mentioned concentration
- the storage bottles may be installed in the protected space; like HALON, no separate storage
- space needed.

Disadvantages:
- not accepted yet by all flag states
- very high refilling cost
- when released into an engine room in fire, toxic gases are formed.

5 Detection

For successful fire-fighting, early detection is of utmost importance. When a person notices fire or smoke, he has to raise the alarm. Buttons are installed throughout the ship, which set off alarms.

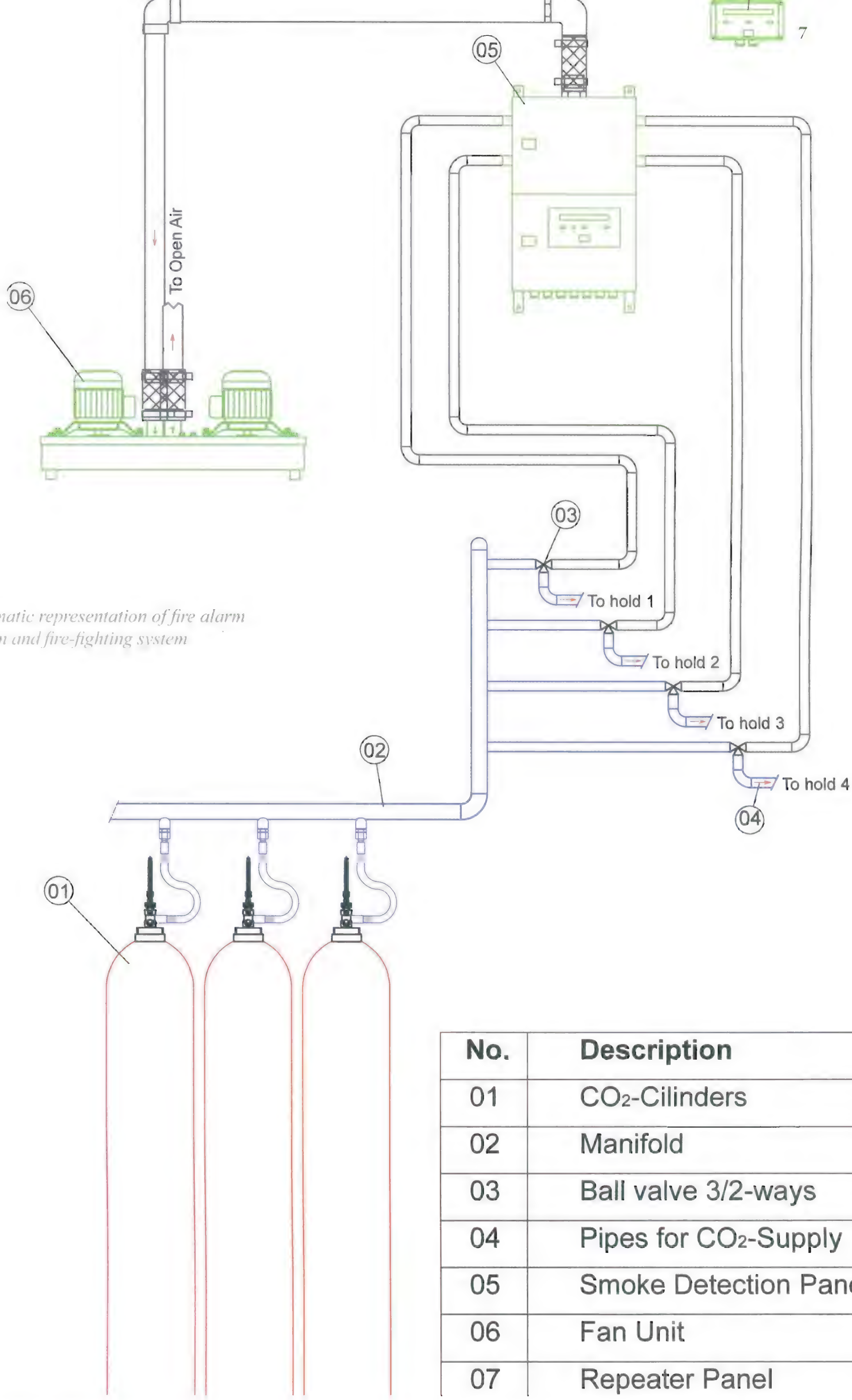
2.5.1 Engine room

In an unmanned engine room, or an engine room which is operated from a control room, a fire detection system has to be installed. Smoke, heat and flame-detectors are fitted at strategic (high) locations, for early detection.

In the engine room, three types of detectors are in use:

Smoke detector: Normally a radioactive isotope which triggers an alarm when the radiation is obstructed; it contacts the alarm cabinet, which raises an alarm. The alarm cabinet is usually in the wheel house. The alarm activates bells, ringing loudly throughout the ship. Which loop is activated can be seen in the cabinet. Each loop covers a certain area in the ship or engine room. Each loop also has heat and flame detectors. Testing of smoke detectors can be done using a small smoke source or special gas.

Heat detector:
A thermo-couple, reacting to a sudden rise in temperature; testing is done by application of a heat source (cigarette lighter).



Schematic representation of fire alarm system and fire-fighting system

No.	Description
01	CO_2-Cilinders
02	Manifold
03	Ball valve 3/2-ways
04	Pipes for CO_2-Supply
05	Smoke Detection Panel
06	Fan Unit
07	Repeater Panel

Flame detector:
A photocell, reacting to shattering light. Testing done by playing with an ordinary flashlight.

2.5.2 Cargo holds

Fire in cargo holds can be detected through **Sample Extraction**. In cargo holds of dry cargo ships an arrangement of suction pipes is fitted, by which gas is extracted from the cargo hold or cargo-compartment. This gas is drawn via a pipeline, one for each compartment, towards a cabinet, in the CO_2 room. In its simplest form, the samples of all spaces are checked one by one by leading the samples through a smoke detector. When smoke is detected an alarm is raised. A detection panel showing which hold is producing smoke, is situated in the wheelhouse. Investigation and action must then be undertaken by the ship's staff. CO_2 can be released as above, using the sample tubes.

2.6 Structural fire protection

Another important issue in fire-fighting is to try to isolate a fire within certain boundaries. Such boundaries are steel divisions, rated A-0 to A-60, depending on their importance and the flammability of the divided spaces.
'A' means that the division is made of steel and is gas tight. The figure behind the 'A' stands for the time the division should withstand a fire so that the temperature does not rise more than 200^0 C on the other side of the division.
B-Class divisions are used inside A-Class boundaries and are only non-combustible, not gastight, so smoke can pass through.

In SOLAS Chapter II, various matrixes are given for the quality of divisions in cargo ships and passenger ships. A stairwell next to an engine room for example, has to be an A-60 boundary.
A steel bulkhead without fire retardant insulation is called A-0. When an approved fire retardant insulation of sufficient thickness is applied, it can be an A-60 boundary.
The arrangements and requirements depend on the type of ship, and for cargo ships, the configuration chosen. When sprinklers are chosen for in the accommodation, the A-class boundaries are less stringent than when there are no sprinklers (or fog systems) fitted.

Cargo ships have 3 possible configurations - Method IC, IIC and IIIC.
IC- all bulkheads and divisions between non-combustible materials A and B-Class. No sprinkler, fire detection and fire alarm required
IIC- bulkheads and divisions have no requirements, but sprinkler, fire detection and fire alarm required
IIIC-fire detection and fire alarm, no restrictions on the type of bulkheads, but spaces must be smaller than 50 m^2

For all three configurations, the boundaries between engine room, control stations, staircases, corridors and the accommodation must be of non-combustible materials and insulation.

In general, the requirements in cargo ships are less stringent than in passenger ships, as on cargo ships all crew members have to be trained in fire fighting, where on passenger ships the crew is trained, but the passengers are normally not.

On passenger ships carrying more than 36 passengers, the hull, superstructure and deckhouses must be subdivided in main vertical zones, with A-60 bulkheads as boundaries, not more than 48 meters apart, and as far as possible in line with the watertight subdivision of the hull.
The requirements for bulkheads, floors, divisions and ship type are provided in a number of matrixes.
The spaces are categorized by SOLAS as follows:

- control spaces
- corridors
- accommodation spaces
- stairways
- service spaces (low risk)
- machinery spaces category A
- other machinery spaces
- cargo spaces
- service spaces (high risk)
- open decks
- Ro-Ro cargo spaces / special category spaces.

2.7 Personal protection for firefighters

Each cargo ship has to be provided with at least two **firefighting outfits**, complete with breathing apparatus. The suit is heat-resistant, with boots, gloves and helmet. In case of smoke, the Breathing Apparatus (BA) is to be used. The BA comprises a compressed air bottle and a smoke mask. A normal tanker has 4 BA sets, chemical tankers, more.

Modern ships are provided with a fire control station. In big ships this is a room in the accommodation, accessible from outside, with a fire door to the rest of the space. The **fire control station**, depending on the type of ship, comprises the following:

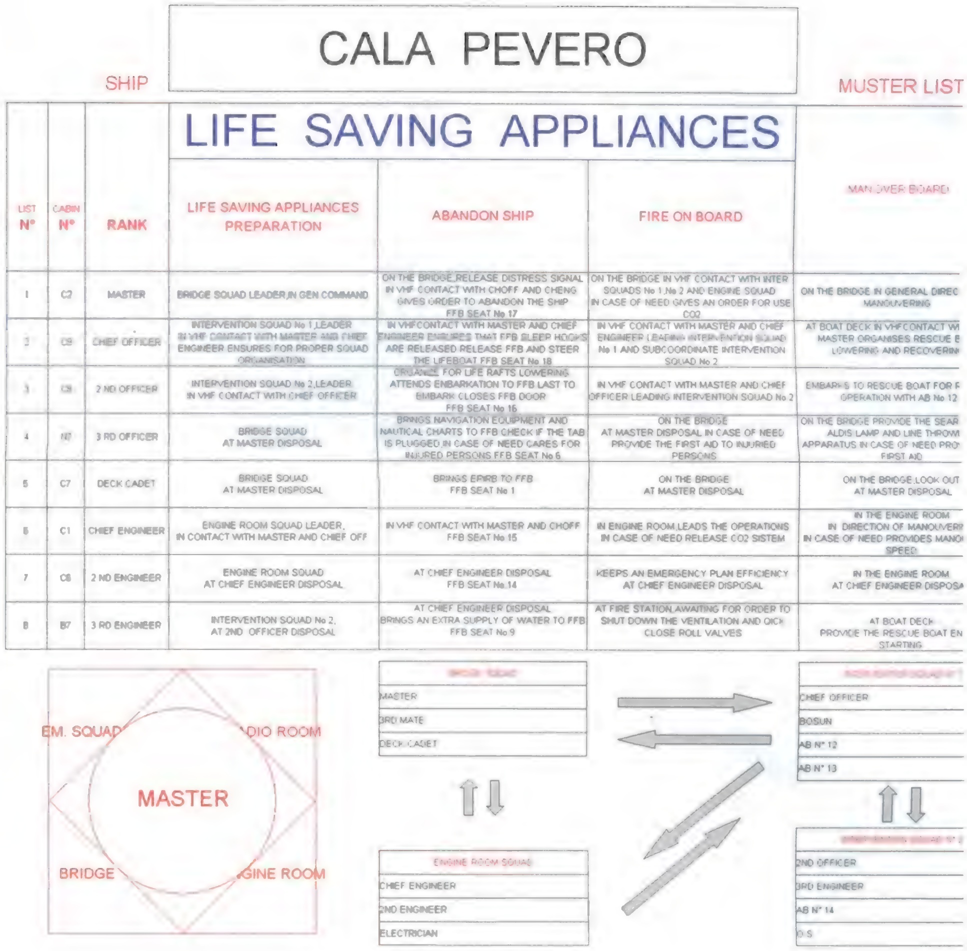
- a display of the fire alarm system,
- the cabinet with the operation handles of the quick-closing valves
- stop buttons for mechanical ventilation
- the smoke extraction cabinet
- the remote operation cabinet of the CO_2 fire extinguishing system
- a fireman's outfit including a breathing apparatus set
- other related equipment

The fire control station is normally also the mustering point for the firefighting team.

Light-weight aluminum fireproof suit.

BA Set (Breathing Apparatus)

1. Mouthpiece
2. Pressure regulator
3. Manometer for bottle pressure
4. Mask



SHIP — CALA PEVERO — MUSTER LIST

LIFE SAVING APPLIANCES

LIST N°	CABIN N°	RANK	LIFE SAVING APPLIANCES PREPARATION	ABANDON SHIP	FIRE ON BOARD	MAN OVER BOARD
1	C2	MASTER	BRIDGE SQUAD LEADER,IN GEN COMMAND	ON THE BRIDGE,RELEASE DISTRESS SIGNAL IN VHF CONTACT WITH CHOFF AND CHENG GIVES ORDER TO ABANDON THE SHIP FFB SEAT No 17	ON THE BRIDGE IN VHF CONTACT WITH INTER SQUADS No 1,No 2 AND ENGINE SQUAD IN CASE OF NEED GIVES AN ORDER FOR USE CO2	ON THE BRIDGE IN GENERAL DIREC MANOUVERING
2	C9	CHIEF OFFICER	INTERVENTION SQUAD No 1,LEADER IN VHF CONTACT WITH MASTER AND CHIEF ENGINEER ENSURES FOR PROPER SQUAD ORGANISATION	IN VHFCONTACT WITH MASTER AND CHIEF ENGINEER ENSURES THAT FFB SLEEP HOOKS ARE RELEASED RELEASE FFB AND STEER THE LIFEBOAT FFB SEAT No 18	IN VHF CONTACT WITH MASTER AND CHIEF ENGINEER LEADING INTERVENTION SQUAD No 1 AND SUBCOORDINATE INTERVENTION SQUAD No 2	AT BOAT DECK IN VHFCONTACT WI MASTER ORGANISES RESCUE B LOWERING AND RECOVERIN
3	C8	2 ND OFFICER	INTERVENTION SQUAD No 2,LEADER IN VHF CONTACT WITH CHIEF OFFICER	ORGANIZE FOR LIFE RAFTS LOWERING ATTENDS EMBARKATION TO FFB LAST TO EMBARK CLOSES FFB DOOR FFB SEAT No 16	IN VHF CONTACT WITH MASTER AND CHIEF OFFICER LEADING INTERVENTION SQUAD No 2	EMBARKS TO RESCUE BOAT FOR F OPERATION WITH AB No 12
4	N7	3 RD OFFICER	BRIDGE SQUAD AT MASTER DISPOSAL	BRINGS NAVIGATION EQUIPMENT AND NAUTICAL CHARTS TO FFB CHECK IF THE TAB IS PLUGGED,IN CASE OF NEED CARES FOR INJURED PERSONS FFB SEAT No 6	ON THE BRIDGE AT MASTER DISPOSAL IN CASE OF NEED PROVIDE THE FIRST AID TO INJURIED PERSONS	ON THE BRIDGE PROVIDE THE SEAR ALDIS LAMP AND LINE THROWI APPARATUS IN CASE OF NEED PRO FIRST AID
5	C7	DECK CADET	BRIDGE SQUAD AT MASTER DISPOSAL	BRINGS EPIRB TO FFB FFB SEAT No 1	ON THE BRIDGE AT MASTER DISPOSAL	ON THE BRIDGE,LOOK OUT AT MASTER DISPOSAL
6	C1	CHIEF ENGINEER	ENGINE ROOM SQUAD LEADER, IN CONTACT WITH MASTER AND CHIEF OFF	IN VHF CONTACT WITH MASTER AND CHOFF FFB SEAT No 15	IN ENGINE ROOM,LEADS THE OPERATIONS IN CASE OF NEED RELEASE CO2 SISTEM	IN THE ENGINE ROOM IN DIRECTION OF MANOUVERI IN CASE OF NEED PROVIDES MANO SPEED
7	C6	2 ND ENGINEER	ENGINE ROOM SQUAD AT CHIEF ENGINEER DISPOSAL	AT CHIEF ENGINEER DISPOSAL FFB SEAT No 14	KEEPS AN EMERGENCY PLAN EFFICIENCY AT CHIEF ENGINEER DISPOSAL	IN THE ENGINE ROOM AT CHIEF ENGINEER DISPOSA
8	B7	3 RD ENGINEER	INTERVENTION SQUAD No 2, AT 2ND OFFICER DISPOSAL	AT CHIEF ENGINEER DISPOSAL BRINGS AN EXTRA SUPPLY OF WATER TO FFB FFB SEAT No 9	AT FIRE STATION,AWAITING FOR ORDER TO SHUT DOWN THE VENTILATION AND QICK CLOSE ROLL VALVES	AT BOAT DECK PROVIDE THE RESCUE BOAT EN STARTING

An example of a part of a Muster List

The **fire control plan** is a general arrangement drawing of the ship, showing all safety appliances. This plan is posted at various places on board. The fire control plan is also in a red container near the gangway for the shore fire brigade, when the ship is in port or at a shipyard.

Cylinder containing safety plan, easily accessible to firefighters

2.8 Fire alarm

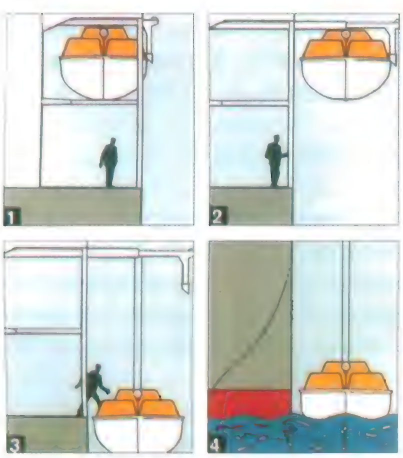
The fire alarm, ringing loudly at intervals of a few seconds, can be activated manually by pushing a button in a little red box, behind glass. The alarm buttons are installed throughout the ship. Also, when fire has been detected by a detection system, it activates the alarm. Resetting of the alarm can only be done at the main display, usually on the bridge. The display indicates which button, in which zone or detection-loop, was activated. A zone or loop can be isolated when repairs are carried out especially if smoke at that location is inevitable (engine room workshop).

2.9 Muster list

A muster list, with names and functions of everyone on board listing emergency tasks, is updated every voyage, and posted at various places - wheel house, mess-rooms and fire control room .

A sprinkler system protects the lifeboat and its occupants against fire

A lifeboat



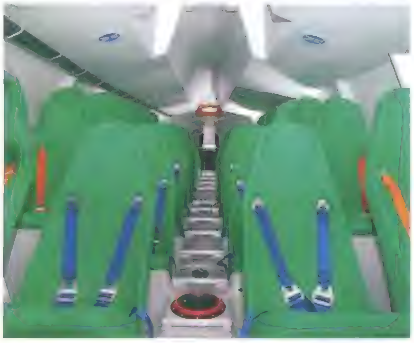
These drawings show how a lifeboat with occupants is embarked and lowered into the water.

Lifeboats launched with stored power davits

Launch of a freefall boat from a height of 20 meter-s

1. Freefall lifebuoy with light and smoke signal
2. Fire hose box, near hydrant
3. Lifebuoy
4. Rescue boat (man over board boat)
5. Life raft (crane launched)
6. Crane for MOB-Boat and Life raft
7. Freefall Lifeboat

New type lifeboat, catamaran type, capacity 40 persons. Note the dome, offering a 360 ° view. The lifeboat is self-righting.



Interior

3. Lifesaving Appliances

3.1 Regulations

Regulations for lifesaving appliances are laid down in the SOLAS Convention. (see Chapter 6).
Chapter III of SOLAS addresses the lifesaving, backed up by the Life-Saving Appliance Code.
The Marine Safety Committee has issued a document with the testing regulations.

3.2 Lifeboats

Lifeboats have to be installed on each side of the ship, each side capable of accommodating everybody on board. Alternatively, a **freefall lifeboat** maybe installed on the stern, large enough to accommodate the whole crew. If there are lifeboats on both sides, one boat is designated as **man over board boat**, or rescue boat. With a freefall lifeboat, an additional man over board boat is needed. On passenger ships, there must be capacity for each person on board, with 50% on each side .

This lifeboat can also be used as a tender on passenger ships.

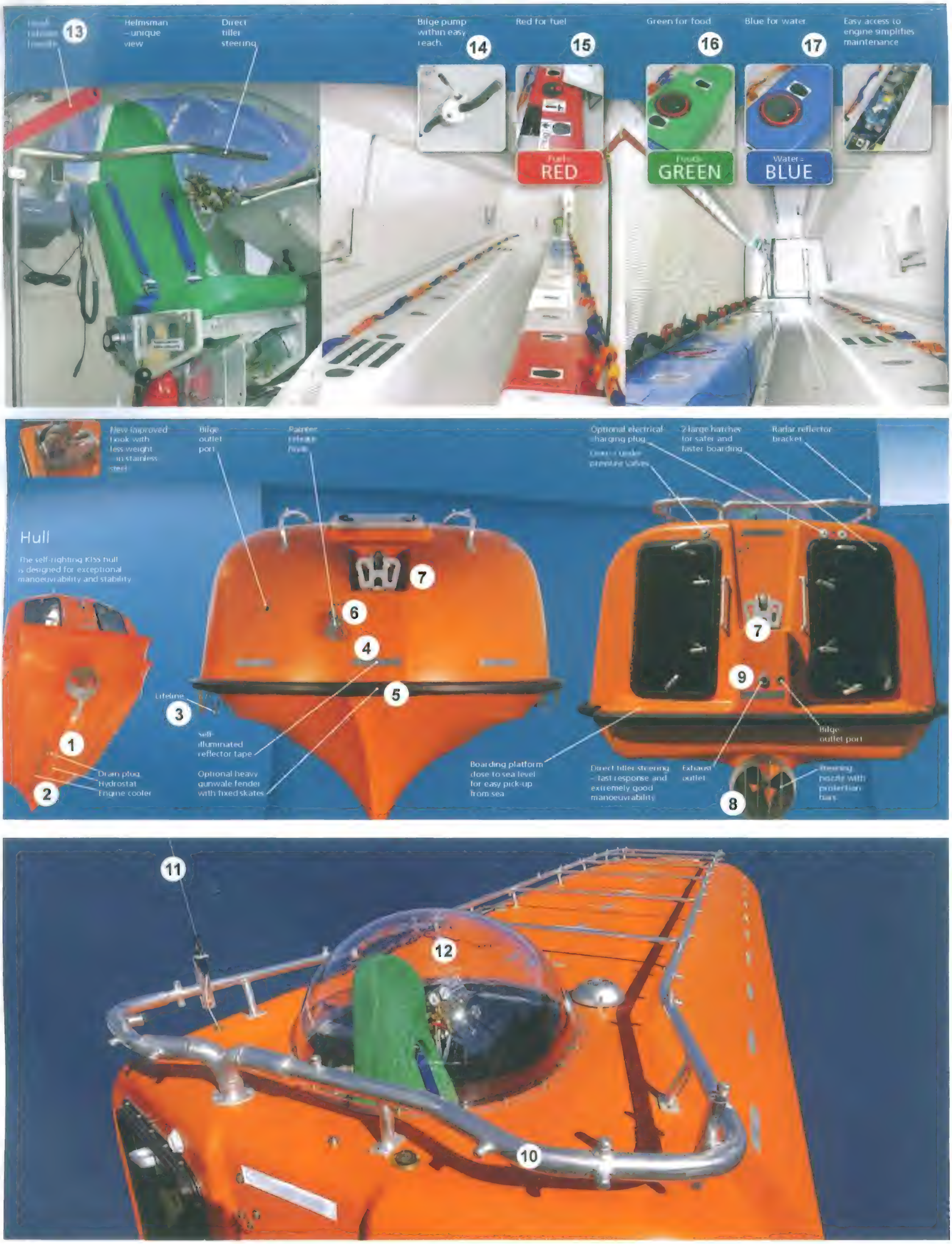
The inventory of the lifeboats is laid down in SOLAS and has to be checked regularly. The main items are food, water, first-aid kit, medicines, searchlight, diesel fuel for 24 hours, two bilge pumps, distress signals, fishing gear, tools such as axes and engine tools, spares, etc.
For the past few years lifeboats have to be totally enclosed. On passenger ships, partially covered boats are used.

The lifeboats on tankers have to be provided with an internal air supply in compressed air bottles, so that the boat can pass through burning oil on the water. Therefore, a sprinkler system is also installed to cool the outside of the boat.

Every lifeboat must have a diesel engine, started by batteries and backed up with a manual start.
Lifeboats have to be able to be launched or lowered when a ship lists, from the high side, with a maximum list of 20° and a trim of 10°. An (enclosed) lifeboat must have sufficient stability to upright itself.

Lifeboats and davits are made in various ways. All systems are made such that no power is needed from the ship's systems to lower a lifeboat.

Freefall type. The installation is positioned aft of the ship, ensuring that trim and list have a minimum influence on launching.



1. Drain plug
2. Cooling water pipes (closed system)
3. Grip lines
4. Reflective tape
5. Fender
6. Release hook for painter
7. Securing hook boat to ship
8. Propeller in nozzle rudder
9. Platform for boarding and taking people out of the water
10. Sprinkler system
11. VHF antenna
12. Dome
13. Handle to release lifeboat for launching
14. Bilge pump
15. Fuel tanks
16. Food tanks
17. Freshwater tanks

Prior to launching, the whole crew enters the boat and seats themselves. Boat securings are released, whereafter the mate moves a lever up and down which lifts the release hook hydraulically. At this point, the diesel engine is already running so that the boat can navigate away from the ship immediately after launching.

The seats in the boat are positioned with the backs facing towards the front of the lifeboat to prevent injuries due to impact.

Apart from falling, the free fall boat can be lowered using the recovery crane, usually an A-frame for testing or maintenance.
The A-frame is provided with a winch, for recovery.

The "auxiliary launching facility" is maneuvered using hydraulic jacks and an electric hoisting winch.
In case the ship sinks or rolls over, the lifeboat must have sufficient buoyancy to detach itself from the launching system.

The most common lifeboat/davit combinations are 'gravity davits' at either side of the ship. The boat drops from its own weight, after removing a number of securings and sea fastenings, by simply lifting the brake handle of the winch.

Another launching method is to use "stored power davits". This system is mainly used on passenger liners because the system does not require much space. The lifeboats hang in the davits.

During launch, these telescopic davits extend until the lifeboat is clear from the ship. The lifeboats can be lowered into the water afterwards. The davits are extended by a hydraulic system that obtains its (stored) power from batteries.

On passenger ships, the lifeboats are also used as tenders to transfer passengers between ship and shore. The boat on page 347 is certified for 120 people when in use as a lifeboat and for 150 passengers when in use as a tender.

Enclosed lifeboats need to be fitted with an on-load hydrostatic release. Unhooking the boat is only possible when the boat is in the water and hydrostatic pressure on a membrane in the bottom allows the release lever to move.

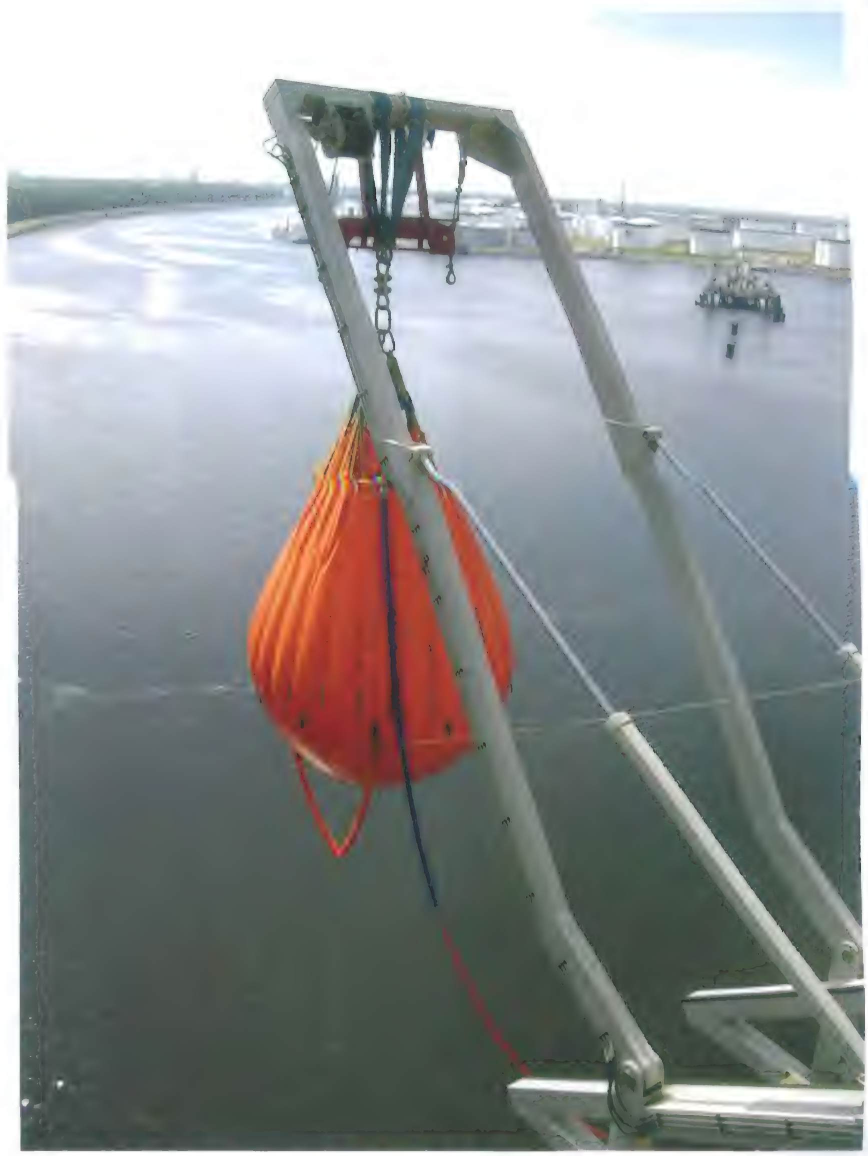
Testing of lifeboats and davits

The davits, have to be (over)load tested every five years. Usually this is done by loading the lifeboat with a weight, equal to the weight of the people the boat is designed for, plus overweight. This means number of people x 75 kgs, plus 10%. The weights are often water bags. The load test is a dynamic test. The boat is lowered by lifting the brake, after which the brake is applied again.

-

Boats, hooks, davits and the on load release system, have to be thoroughly examined yearly. This is normally done by the manufacturers or another approved firm. Boats and davits are also important items for the yearly survey of Safety Equipment, by flag-state or Classification.

The other picture shows the load test of a retrieval davit of a freefall boat. This portal crane is only used to take the boat back on board and, when freefall testing (which has to be done every 3 months) is not practicable, for controlled launching, by hoisting the boat into the water.



Load test of a freefall retrieval crane using a water bag

3.3 Man Over Board boat / rescue boat.

Man Over Board boat / Rescue boat (MOB-boat). In case of a freefall lifeboat, there has to be a separate MOB-boat under a crane. Compulsory inventory includes special survival suits for 3 crewmembers. Ships carrying passengers need to have a fast rescue boat, capable of being lowered into the water when the ship has a speed of 5 knots.

MOB -boat with the crane. The crane can also bring the boat back on board.

Permanent MOB -boat. If the boat is suspended from the crane, it can be lowered by pulling the triangle.

3.4 Life rafts

Inflatable life rafts are located on each side for the whole complement. Davit launchable rafts are required when the embarkation level exceeds 4.5 m above "lightest seagoing condition of the vessel.
Also rafts may be deployed of the type to be thrown overboard maybe deployed.
These rafts must have a line attached to the vessel.
A normal cargo ship with lifeboats, has the 'throw overboard' type.

Raft in container

Explanation of the numbers used in the image below:

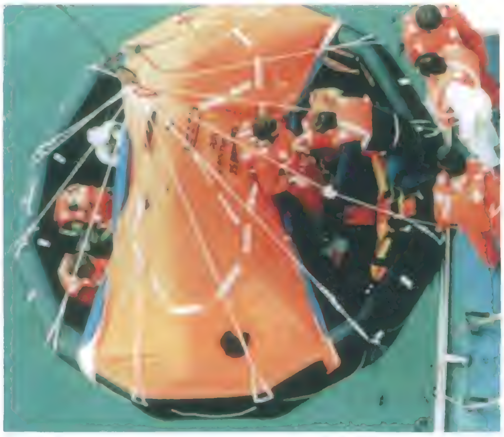
1. Lashing strap around raft
2. Pelican hook
3. Connecting line
4. Painter
5. Weak link
6. Ring
7. Hydrostatic release unit
8. Expiring date of certificate

Hydrostatic release

A launched raft

The sinking ship pulls the boat line and the raft is inflated.

life raft that can be lowered



life raft that can be lowered

In case of a freefall lifeboat, one of the rafts needs to be davit-launched, usually the MOB davit. This allows the life raft to be lowered in inflated condition. The davit has a special hook, which cannot be opened when there is a load or vibrations.

A throw-overboard life raft needs to be connected to the ship by a line, and sea fastened with a band and closed by a hydrostatic release. Pulling the line by dropping the closed raft, triggers the pressurized bottle and inflates the raft. If the ships sinks, the release opens and the raft floats. The connected end of the line has a 'weak link', so that the line can be pulled free.
Large ships have an additional 6-person life raft forward and some very large container ships with midships accommodation, another one aft.

3.5 Life jackets

Life jackets are provided for everyone on board. They must have a light and whistle. They are usually stored in the cabins, but sometimes in boxes near the lifeboats. Also a few life jackets are stored in places where people work - in engine room, bridge and forecastle space. A life jacket has to be made of watertight and fire retarding material with sufficient buoyancy. Furthermore, it has to hold an unconscious person who is face down in the water, upright and has to keep his mouth 12 cm above the water.
They have to be provided with reflective material. In case of children on board, special, smaller life jackets need to be provided. In case of inflatable life jackets, they need to have two air chambers and must be serviced every year.

3.6 Life buoys

A number of life buoys, depending on the ship's length, are positioned around the ship and hooked on the handrails. Some are provided with a light and/or line.
On both bridge wings there has to be a life buoy, that when released, drops by gravity into the sea. Attached to these buoys are a floating smoke light and a light signal.

Life buoy with light

Light and smoke signal

A survival suit has to be worn in combination with a life belt to stabilize the head in case the person wearing it is unconscious

3.7 Immersion suits (survival suits)

As of July 2006, everybody on board a cargo ship, including bulk carriers, has to have an immersion suit.
Hypothermia is the most dangerous threat to people in lifeboats. Especially in open lifeboats, which are still very much in use on older ships. In that case there must be a Thermo Protective Aid (TPA), a protective bag that keeps body heat inside, for the people who do not have an immersion suit.
An immersion suit has to be worn together with a life jacket. The insulating quality of immersion suits has to be such that the body temperature does not drop more than 2 ºC after 6 hours in water with a temperature between 0 and 2 ºC.

4 Precautionary measures

4.1 Training

To work professionally with all the above equipment and items, the ship's crew needs to be educated. Before signing on, everyone must have a certificate of competency.

This certificate can only be obtained when the individual is in possession of the proper diplomas, sufficient sea service and a number of certificates obtained after fulfilling certain safety courses.

4.2 Tests and drills.

To respond quickly and efficiently in case of accident, people need to be trained. Regular drills, fire-drills, and abandon-ship drills, are compulsory. It is important that the drills are as realistic as possible. On completion of the drill an evaluation should be made where the shortcomings of the group or individuals are discussed and if necessary, theory is reviewed. The drills are entered in the ship's logbook. Drills on board with life rafts is impractical and are therefore, conducted at shore institutes. The same applies to distress signals.

Exercise	How many times?
Abandon ship	Monthly
Firefighting	Monthly
Man over board	Monthly
Emergency Steering	Once every three months

Abandon ship drill

Fire drill

4.3 Personal safety gear

During normal daily work, various safety measures have to be taken. Personal safety items for normal work are safety helmet, ear protection, eye protection, gloves, safety shoes, coveralls, lifebelt, etc.

Working with cargo, requires the relevant safety measures related to that cargo, especially when working with chemicals. Often special suits, gloves, boots, breathing apparatus, etc.

4.1 TRAINING MATRIX CARGO SHIPS								PRELIMINARY VERSION 01/2001					add for TANKERS	
TRAINING:	familia-rization (ship specific)	basic training	proficiency in survival crafts etc.	proficiency in fast rescue boats	advanced fire fighting for seafarers	ship health care B	ship health care O (*)	ship manage-ment	radar observer	radar navigator	Marcom A GOC (**)	Marcom B (ROC)	tanker familiari zation	specia-lized training programme
Guide on Training..., chapter 5, paragraph	5.1	5.2	5.3a	5.3b	5.4	5.5	5.6	5.7 Holders of Dutch diploma's only	5.8a	5.8b	5.9	5.10	5.11	5.12
COMPETENCE:														
master														
chief mate								********		********				
watchkeeping officer														
chief engineer								********						
2nd engineer														
watchkeeping eng.														
1st maritime officer								********		********				
maritime officer														
ship's cook														
ratings														
validity in months	n.a.	s.s.	s.s.	60	60	60	60	n.a.	n.a.	n.a.	n.a.	n.a.	n.a	s s

LEGEND:

	= initial training as part of the curriculum of nautical colleges in the Netherlands
(*)	= applicable to ships certified for an unlimited area (GMDSS sea areas A3 and A4)
(**)	= required for at minimum 2 officers in charge of a navigational watch **(presently all officers in charge of a navigational watch)**
	= mandatory
	= mandatory only for designated crew (according to the vessel's manning plan or muster list)
**********************	= not applicable to certificates of competence < 3000 GT and/or < 3000 kW
n.a.	= not applicable
s.s.	= no refresher training required in case of 1 year sea service during the past 5 years

Training matrix in accordance with 1995 STCW-treaty. The table shows an overview of required exercises for working on passenger ships, safety exercises are included. The table is from the Royal Association of Dutch Owners (KVNR), in collaboration with the Association of Dredging and Civil engineering companies (VBKO) and the Shipping Inspectorate. The data in the table has a temporary status and is based on the situation in 2005. The matrix for cargo ships is somewhat different. No training in handling large groups of people in emergencies is included here.

MARS 200031
Saved by a Safety Helmet

A 2nd Mate was in charge on the deck of a ship which was at anchor and loading containers from barges. As a container was being loaded on to the 3rd layer by stevedores a twistlock fell from a height of about 8 metres. It hit the 2nd Mate on his helmet and touched his body causing an abrasion on his chest and a contusion on his left thigh. Because of the heavy impact on his head he was sent ashore to see a doctor.

An X-Ray was taken and he was declared fit to return to the vessel but put on light duties. This emphasises the importance of wearing personal protective equipment, without his helmet the 2nd Mate would probably have died.

Safety helmet and a self-inflating life jacket, used during work.

Some examples of filter masks. The left one also protects the eyes from poison.

4.4 Tankers

Tankers have special safety measures, with additional firefighting systems, such as:

- a foam system to cover the deck
- fire and / or explosion prevention by inert gas above the cargo
- alarms for full tank or risk of overfill (95% and 98% full)
- special safety measures for the cargo pump room.

5 Markings

Many items are identified by markings, often stickers. All safety gear, wherever stored, has to be indicated by a sticker. Escape routes are also identified by stickers.

Instructions on how to use the life rafts must be displayed near the rafts, i.e. showing preparation and launching.

Markings should be clear, simple and easy to understand. For instance, on ships carrying passengers, station numbers are useful for orientation of the passengers on the ship. However, the markings are important for both crew and passengers in case of emergency. The markings show the exits and the location of life-saving appliances. This is made easier by the use of arrows on the walls or a lighting system for passageways and staircases. These escape route markings (green) in the accommo-dation are compulsory according to IMO-regulations. Not only the escape route must be marked, but also safety measures. The markings on these should be photo-luminescent. This means that they light up when no light shines on them.

Many pipes run through the engine room and ship. A large variety of liquids is pumped through these pipes and should clearly indicate which liquid runs through which pipe. This is not only important for the crew, but also for people less familiar with the ship. To achieve this all the pipes have a color (either paint or colored tape) that represents the liquid in that pipe.

Testing the foam pump on a tanker

Entrance door with name and technical marking

Farbcode: Colour code:	Farbe: Colour:	Medien (allgemein): Media (general)
BU Blue		Frischwasser Fresh water
GN Green		Seewasser Seawater
SR Silver		Dampf Steam
RD Red		Feuerbekämpfung / Feuerschutz Fire fighting / Fire protection
YEO Yellow-ochre		Entflammbare Gase Flammable gases
WH White		Luft im Ventilationssystemen Air in ventilation systems
BN Brown		Kraftstoffe Fuels
OG Orange		Öl (nicht zum Kraftstoffgebrauch) Oil other than fuel
VT Violet		Säuren, Laugen Acids, alkalis
GY Grey		Nichtbrennbare Gase Non flammable gases
MN Maroon		Medien (trocken und feucht) Masses (dry and wet)
BK Black		Abwasser / Abgase Waste media
FD	←	Fließrichtung Flow direction

Color code for pipes

Pipe with color code and arrows indicating the direction of the liquid flow

Arrows

Sticker showing one's position on board

Emergency lighting system

There are many large and small rooms and spaces on a ship. In general each has a door or an entrance hatch. But before the door or hatch is opened, it is important to know what is in that particular space, especially at night or in bad weather. This is why every door or hatch carries the name of the room behind it, sometimes with a technical marking.

6 Communication Safety

6.1 Global Maritime Distress and Safety System (GMDSS)

A GMDSS installation is legally required by the SOLAS 74 Amendment in which the distress and safety radio traffic is regulated. All passenger liners and ships larger than 300 GT are obliged to have GMDSS. GMDSS ensures that, irrespective of the ship's location, reliable shore to ship and ship to shore communication is possible in an emergency using radio and/or satellites. All information regarding transmitting and receiving, and the frequencies used, can be found in the "Admiralty List of Radio Signals", Volume 5. GMDSS also includes the NAVTEX receiver, which receives and prints weather forecasts and warnings as well as distress messages, and watertight (GMDSS) walkie-talkies for communication in case of distress.

NAVTEX

DSC2. GMDSS Control Panel

6.2 SART (Search and Rescue Transponder)

Life rafts and lifeboats are difficult to see on radar because of their poor radar-reflecting properties. To overcome this problem, a device (SART) has been developed that, on receiving a radio signal, answers by transmitting a radio signal of the same frequency. This makes the life raft or lifeboat visible on the radar screen. When the ship is evacuated, one individual, indicated on the Muster List, is responsible for bringing the SART from the bridge, to the life raft or lifeboat. The SART has a range of approximately 30 miles.

6.3 EPIRB (Emergency Position Indicating Radio Beacon)

The EPIRB is of use in case the ship is sinking so fast that the crew does not have the time to warn the world of the disaster. As in the case of the life raft, the water pressure will activate a hydrostatic release and the EPIRB will rise to the surface. As soon as the EPIRB is activated it will start to transmit the MMSI-number* of the ship to a satellite which, in turn, will warn a ground station. The ground station then warns the nearest coast guard station. **(*MMSI= Maritime Mobile Ship's Identification)**
The coast guard will direct ships and aircraft as soon as the approximate position of the ship in distress is determined. When the EPIRB starts transmitting, a bearing can be taken and the position can be determined.

Bridge, starboard side

1. SART
2. Powder extinguisher
3. CO_2-extinguisher 2 kg

SART attached to the life raft

Aft side of the bridge

1. EPIRB
2. Fire hose box, with contents: hose, nozzle and spanner

6.4 Voyage Data Recorder (Black Box)

At present phasing in for ships of 3000 GT and upwards, starting with 20,000 GT and upwards, ships are required to have a Voyage Data Recorder (VDR).
This is an apparatus storing in a secure and retrievable form, the data of navigation, such as position, movement, speed, course, command and control (recordings of voice on the bridge, etc.) leading up to and after an incident or accident.

7. Pyrotechnics

A visual form of emergency communication are the Distress Signals:

Red Parachute Signals, must be available in or near the wheel house (12) and in each lifeboat (4). They are rockets, which can be fired out of hand and can be seen from a great distance to be fired in the hope somebody notices. The general meaning is: I need help.

Hand flares, in lifeboats (6) and rescue boat (4). These are very bright hand-held burning torches used to draw attention or indentify location.
Smoke signals, in each lifeboat (2). A tin can, when lit to be put in the water. They remain afloat and produce a thick orange smoke, clearly visible from airplanes.

Line throwing apparatus, 4 pieces in or near the wheel house. These are rockets, which when fired by a gun, draw a long thin line behind them. The purpose is to shoot a line to another ship, as a first step towards establishing a towing connection. With the thin line a somewhat heavier line can be pulled in, connected to a hawser.

Line throwing apparatus

Smoke signal

Parachute light

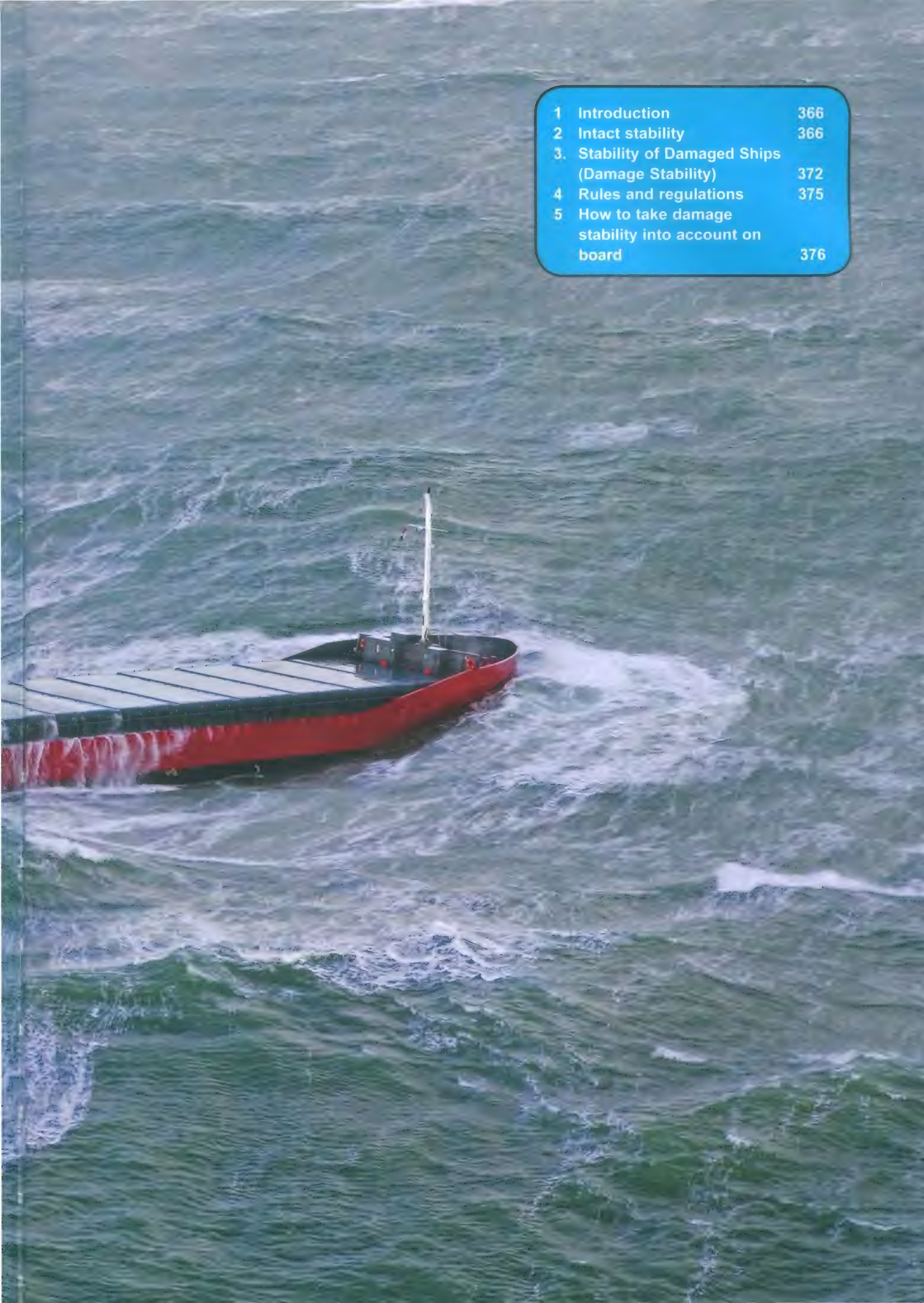
Hand torch

Hand flares

During tank cleaning on a chemical tanker, static-electricity has developed. An explosion followed. Mechanical ventilation to allow too-lean washing, was possibly carried out inadequately. Too lean means that the atmosphere in the tanks is kept below the low explosion level.

CHAPTER 16

Stability



1. Introduction

Why does a ship float in spite of being constructed from heavy materials such as steel? The reason for this is that the gravitational force that pulls the ship downwards is balanced by the upward water pressure on the hull. Of course a prerequisite for this is that the ship is watertight below the waterline. When the weight of the ship becomes so large that the upward pressure is less than the actual weight, the ship will sink.

> The water around the ship exerts a force on the ship perpendicular to the water surface. If the ship floats, this force equals the weight of the water displaced by the ship. This is called Archimedes' law which states that an object that is totally or partially submerged in a liquid, experiences an upward force that equals the weight of the displaced liquid.

The magnitude of the upward force depends on the volume of the ship's underwater body.
The displacement resulting in an upward force is called buoyancy. If the ship has only buoyancy (B) and no reserve buoyancy above the waterline, then the slightest increase in weight of the ship would cause it to sink.
It is therefore very important that the ship possesses a certain amount of reserve buoyancy. The reserve buoyancy comprises the hull volume above the waterline, but also the accommodation, deckhouses and other deck erections.
All the spaces that contribute to the reserve buoyancy must be watertight or able to be closed watertight.

2. Intact stability

Ships are designed to float upright, and thus, must have stability.

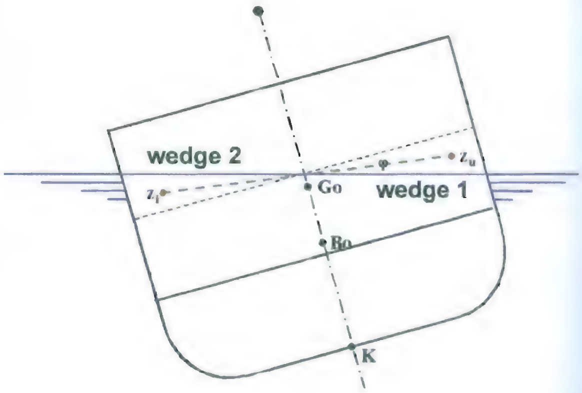
A distincion is made between longitudinal stability and transverse stability. Longitudinal stability is normally sufficient, therefore, will not be taken into consideration. When the word stability is mentioned, it refers to transverse stability.

Stability for small list angles of heel (less than 6°) is called Initial Stability.

When a floating body is forced into a heeled position without adding or removing weight, a buoyancy wedge (2) is formed and filled at the lower side of the body, and at the high side a wedge (1) is lost. When the volume of the submerged part does not change, both wedges have the same volume.

Due to the above water movement (from wedge 1 to wedge 2), the center of buoyancy (B) of the whole submerged part has moved. B is the center of gravity of the displaced liquid, and at that point the vector representing the buoyancy has its origin.

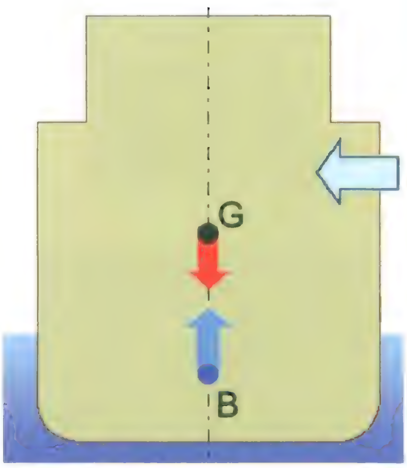
> Stability is the ability of a totally or partially submerged body to float upright, and when forced from the upright position, to come back to the upright position when the reason for the list no longer exists.



The locations of B at varying angles are all on a virtual curve.

A ship can be forced to a heel in all directions, not just transversely or longitudinally.
Here, only two models are considered - transverse and longitudinal, which are at right angles to each other

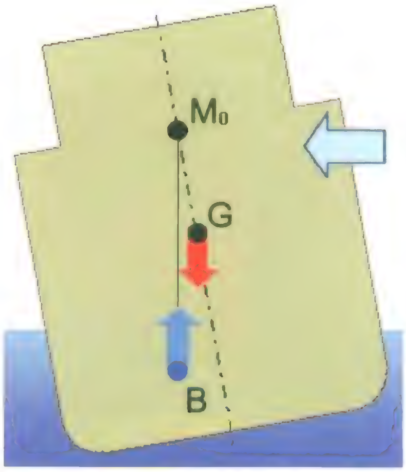
The following pictures show a transversal section of a ship. In the figure below, we see the points 'G' for Gravity and 'B' for Buoyancy, both origin of a vector, representing the forces of weight and buoyancy.



With a strong wind from transverse direction, the ship lists slightly, resulting in a transformation of the buoyancy, and relocation of vector B to the low side of the ship, but transversally to the waterline.

Point M, or the Metacenter, is found where the buoyancy vector crosses the centerline of the ship.

For every angle of list and displacement, there is 1 metacenter point. In case of larger heel, the position of M can vary considerably in comparison to M for small angles of heel. In this case, it is called the False Metacenter.



Metacenter (M): The point at which where the ship is virtually suspended. The height of M is important to initial stability

2.1 Determination of the distances MB, KG and KB

MB
The vertical distance between M and B can be determined using the formula:

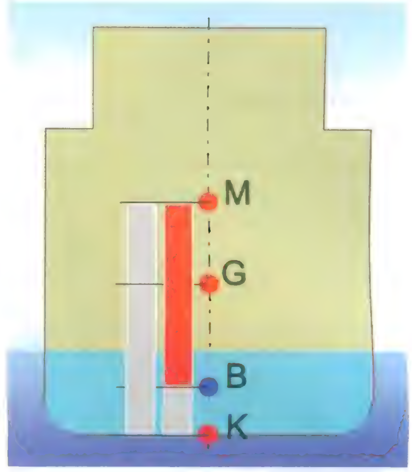
I = transversal moment of

$$MB = \frac{I_t}{V}$$

inertia of the waterline area = 1/12 LB^3 [m^4] (only in case of a rectangular barge.)
V = volume submerged part of the ship [m^3]
L = length of the submerged part of the ship [m]
B = breadth of the submerged part of the ship [m]

MB can be found for every draught (T) in the ship's hydrostatic tables or can be calculated.

KG
The distance from the center of gravity of the complete ship to the keel 'K' (KG) is (initially) a figure produced by the building yard.
Each added weight afterwards, results in a change of KG. (unless added at the level of G)
Added weights include cargo, stores, fuel, drinking water, ballast, personal belongings and everything else not belonging to the empty ship.

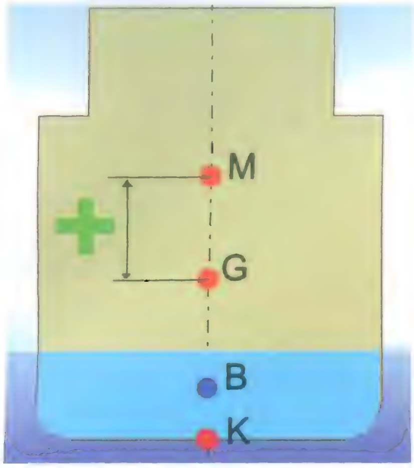


KB
KB can be found for each T in the hydrostatic tables of the ship.
The tables are found in the Hydrostatic Particulars, supplied by the building yard and have to be carried on board. (stamped and signed by the flagstate as appropriate and approved for the particular ship).

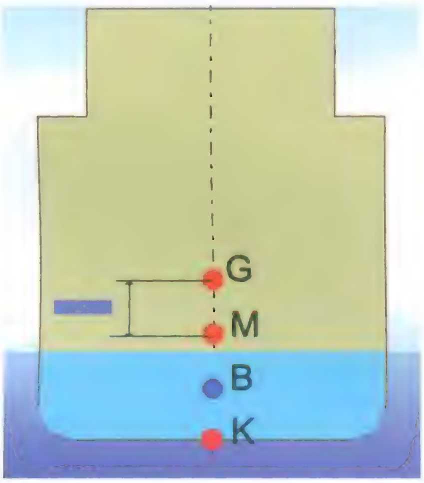
This cargo hold of a multi purpose ship is being loaded with piles for the offshore industry. The length of one pile, is as long as the cargo hold. Division bulkheads are removed. This type of pile is used to attach a jacket to the seabed. The first piles are loaded in the hold. G moves down and KG decreases. After one layer of piles, causing a gradual decrease of KG, the next layers will increase KG. If the hold is filled completely, KG will have an acceptable value.

2.2 GM values

GM can have three values:
- GM positive: M above G
- GM negative: M below G
- GM zero: M and G are at the same location. (KM = KG)



MG is positive



MG is negative

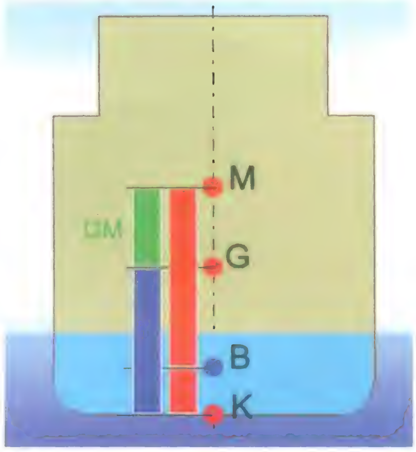
2.3 The location of G in relation to M (GM)

When the aforementioned distances are determined, the distance between G and M (GM) can be calculated. This distance is decisive for the length of the 'righting arm' which is decisive for the 'righting moment' or 'stability moment'.

The value of GM comes from the formula:

GM = KB + BM - KG
GM = KM - KG

The above alternatives are only applicable for small angles of heel. i.e. less than 6°, is the initial stability.



2.4 The importance of the length of the righting lever of the stability moment

A ship under heel illustrated in the figure on the following page.
The cause of the list is external - a wave or wind pressure.
This results in B moving to the low side of the ship. The stability moment is shown as (Δ x GZ).

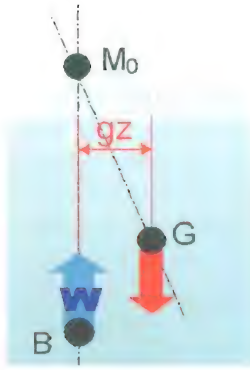
$$\text{Sin } \varphi = \frac{GZ}{GM} \rightarrow GZ = GM \sin \varphi$$

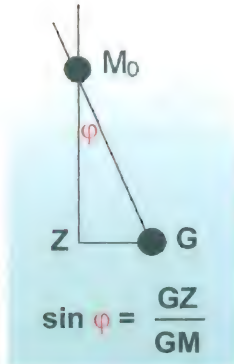
The figure shows that the magnitude of stability moment depends on the horizontal distance between the two forces (buoyancy and displacement), the so-called static lever of stability, GZ.

These levers can be calculated for different angles of heel.
When set against a baseline, a curve is found, the 'curve of levers of static stability', or the stability curve.
The values are usually given in meters.

The stability curve gives a clear picture of the ship's stability and has to meet legal requirements.

Δ = displacement



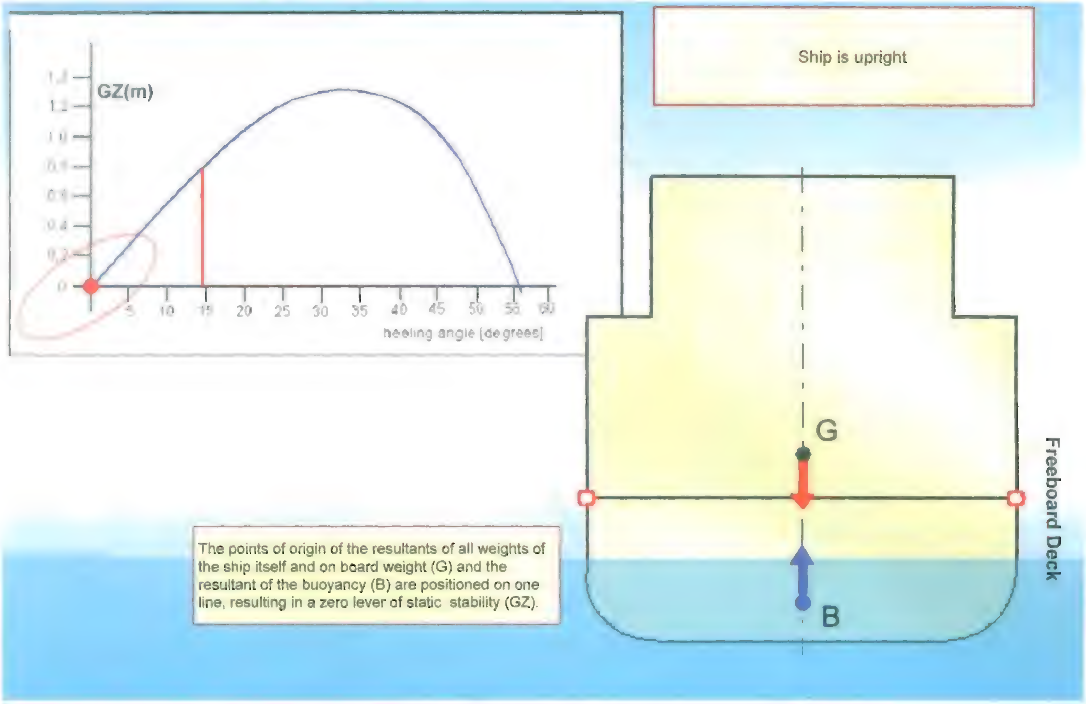


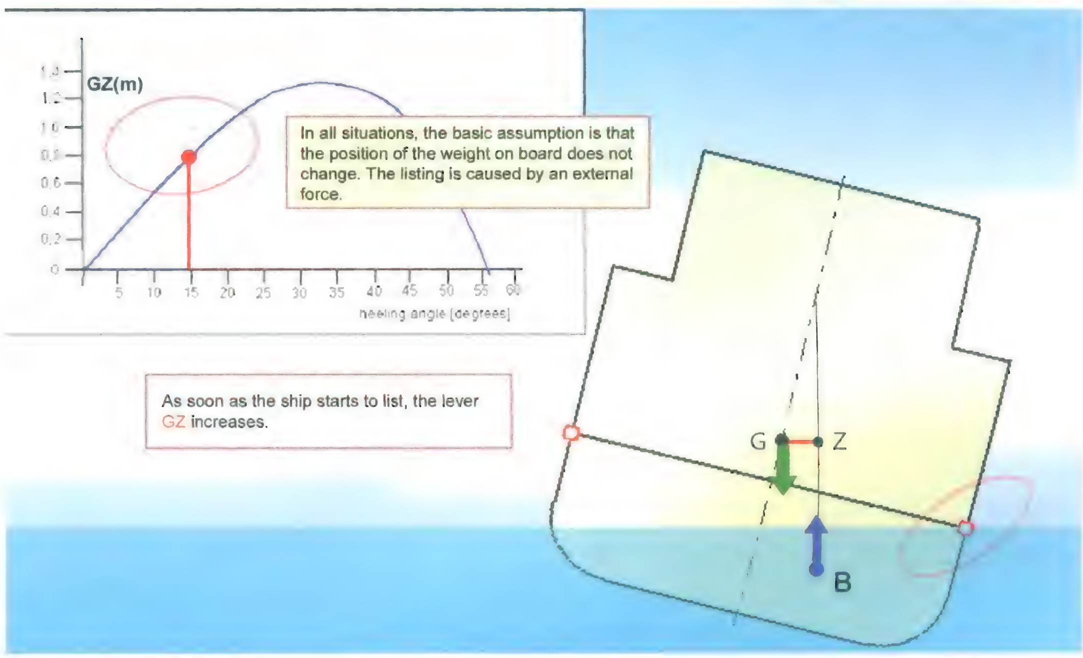
A couple is a system of two identical opposing forces working on a body along parallel lines. The magnitude is "force x lever". In the case of a ship this is: Δ x GZ

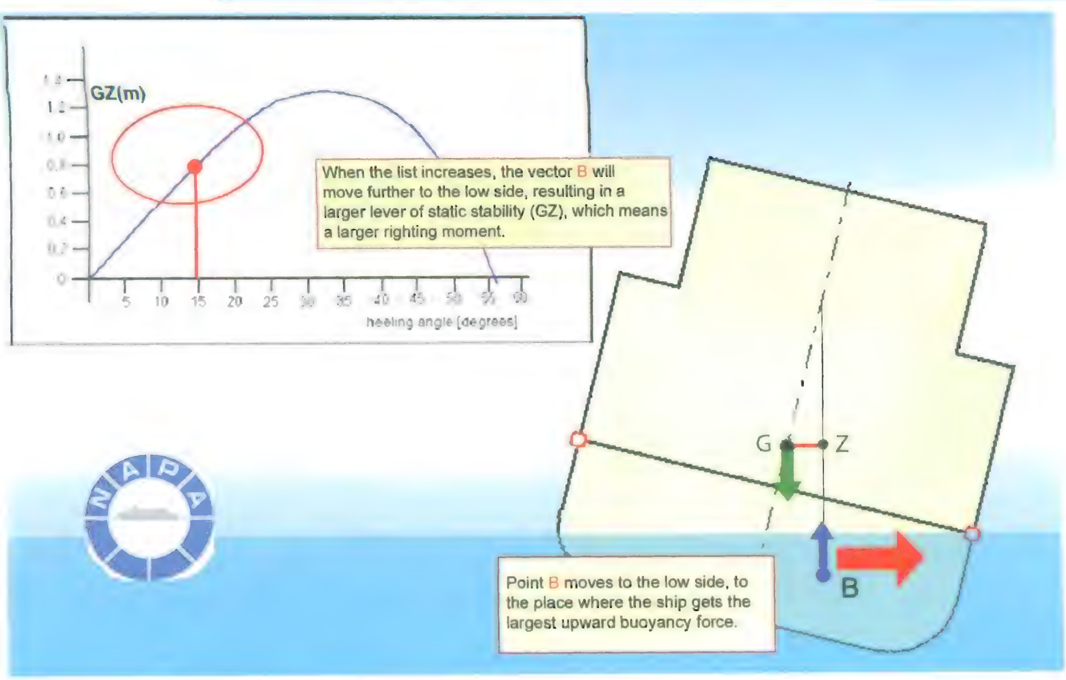
Relation between waterline area and M
From the formula MB=I/Vol it is apparent that the location of M, with a constant ship weight, completely depends on the waterline area.

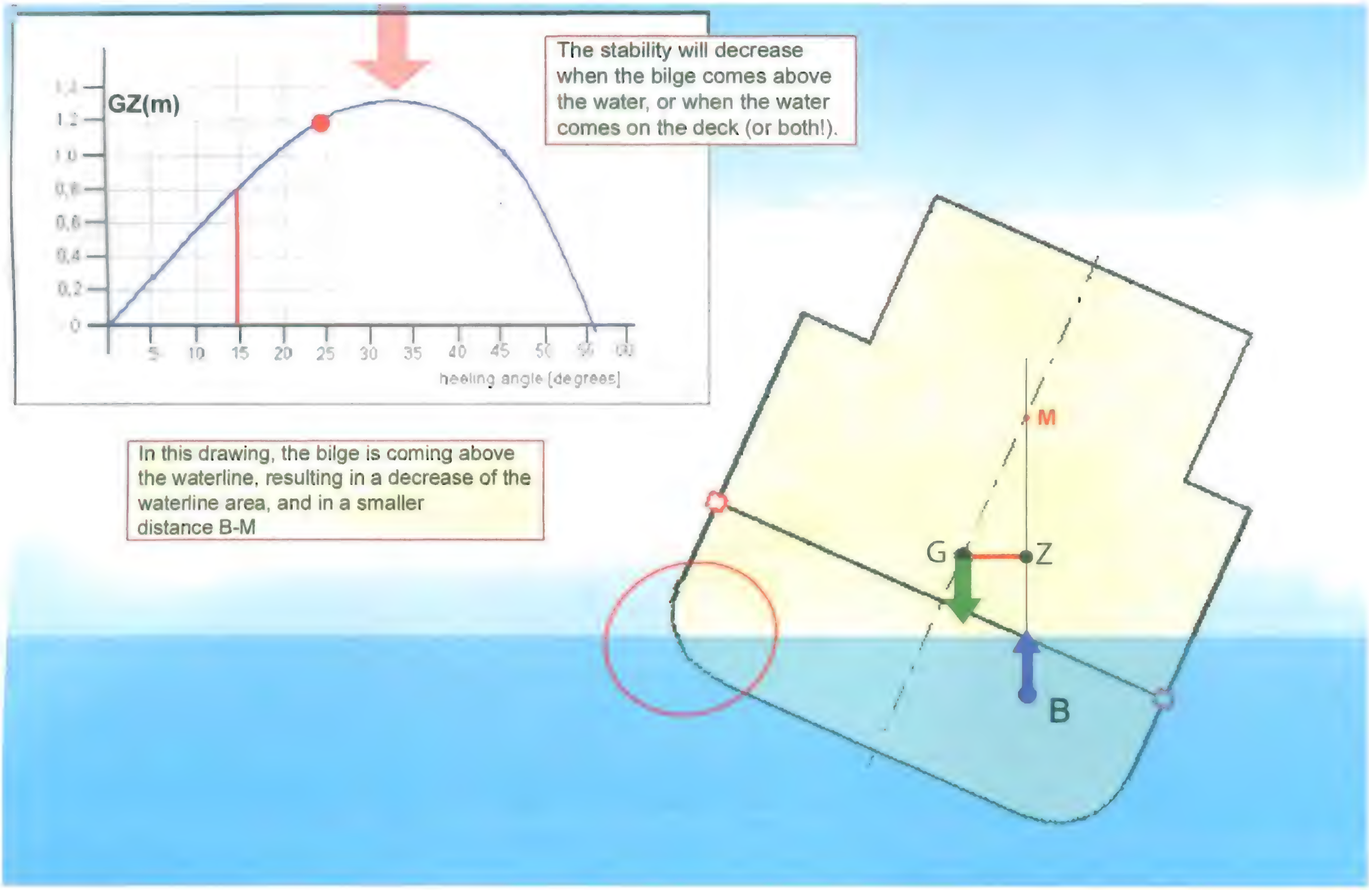
When a ship heels, the breadth of the waterline increases, and thus area of the waterline, resulting in an increase of MB. In this way, a small negative initial MB, becomes positive, preventing the capsizing of the ship.

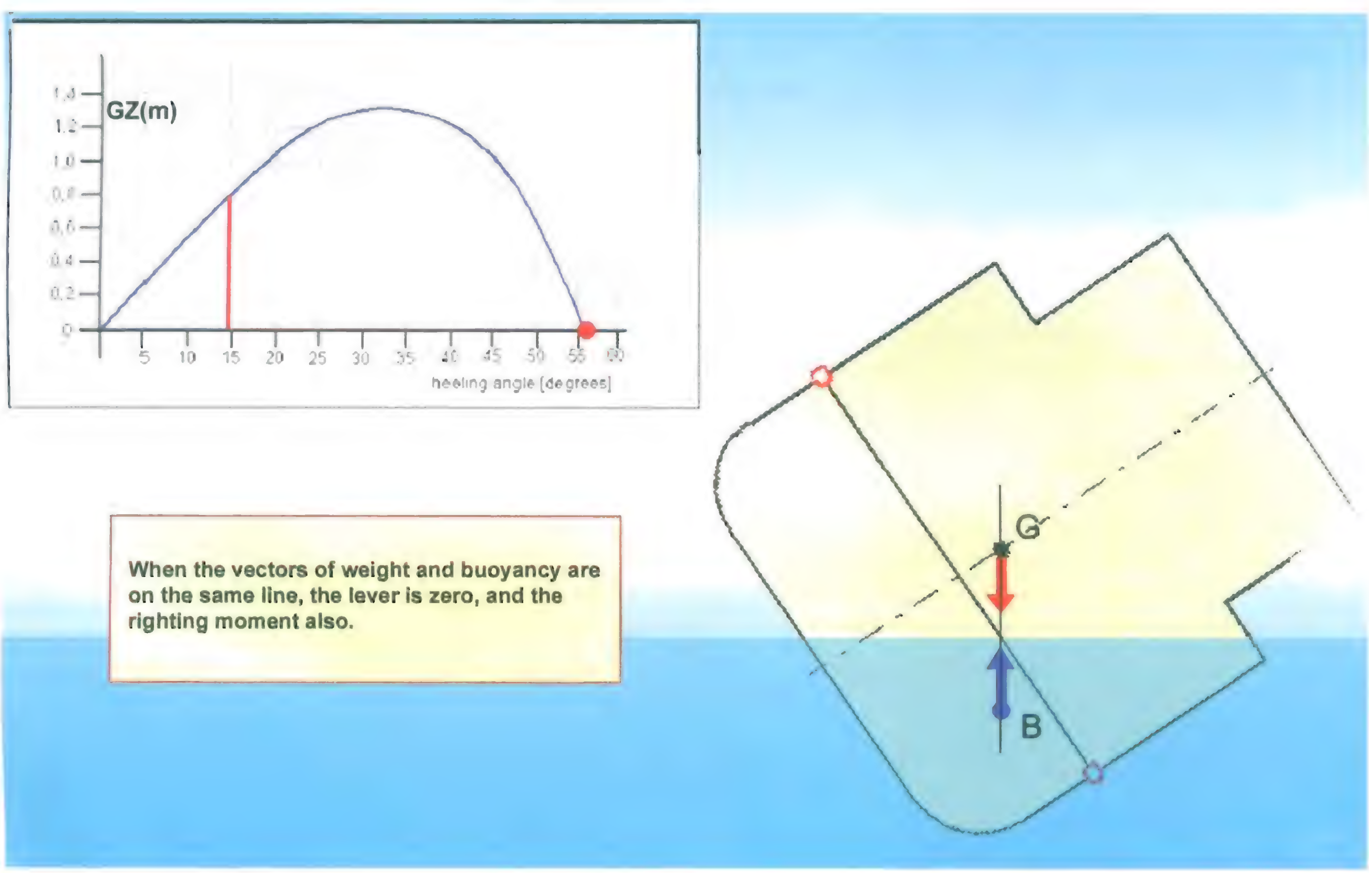
The opposite can occur when for instance by ballasting a forepeak the trim changes, resulting in a decrease of waterline area. Fast ships normally have a smaller waterline area fore than aft.

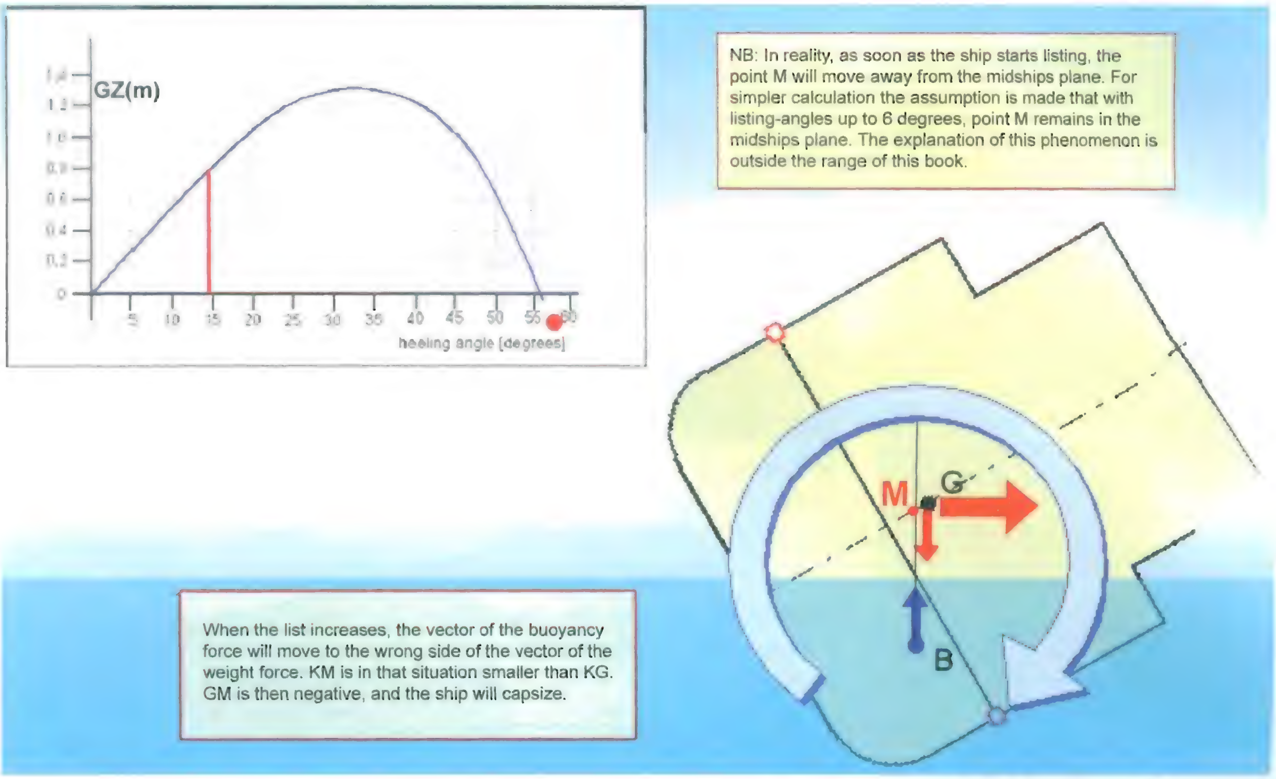

Ship is upright
GZ(m)
heeling angle [degrees]
G
B
Freeboard Deck
The points of origin of the resultants of all weights of the ship itself and on board weight (G) and the resultant of the buoyancy (B) are positioned on one line, resulting in a zero lever of static stability (GZ).


GZ(m)
heeling angle [degrees]
In all situations, the basic assumption is that the position of the weight on board does not change. The listing is caused by an external force.
As soon as the ship starts to list, the lever GZ increases.
G
Z
B


GZ(m)
heeling angle [degrees]
When the list increases, the vector B will move further to the low side, resulting in a larger lever of static stability (GZ), which means a larger righting moment.
G
Z
B
Point B moves to the low side, to the place where the ship gets the largest upward buoyancy force.


GZ(m)
0
0,2
0,4
0,6
0,8
1,0
1,2
1,4
5 10 15 20 25 30 35 40 45 50 55 60
heeling angle [degrees]
The stability will decrease when the bilge comes above the water, or when the water comes on the deck (or both!).
In this drawing, the bilge is coming above the waterline, resulting in a decrease of the waterline area, and in a smaller distance B-M
M
G
Z
B


GZ(m)
0
0,2
0,4
0,6
0,8
1,0
1,2
1,4
5 10 15 20 25 30 35 40 45 50 55 60
heeling angle [degrees]
When the vectors of weight and buoyancy are on the same line, the lever is zero, and the righting moment also.
G
B



2.5 Notes on stability

2.5.1 Influence of Depth on stability

The figures below demonstrate why a greater Depth (D) or a greater freeboard are important for stability.

Both ships have the same GM-value, but a different stability range, 34º and 47º respectively. The beam of both ships is the same. The depth of hull nr. 2 is larger than that the depth of hull nr. 1

2.5.2 Influence of GM_0

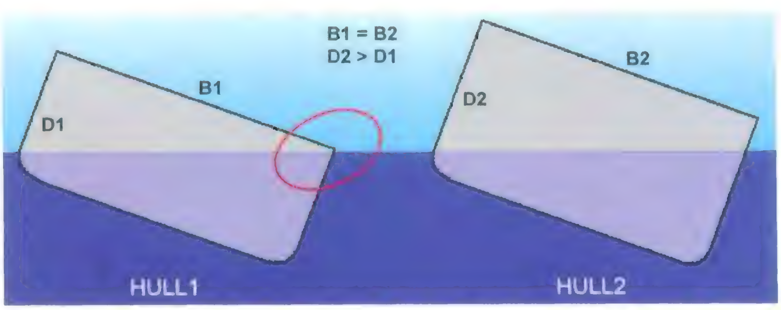
The minimum and maximum values of GM_0 is largely depen-ding on the type of ship. Varia-tions between 0.5 m and 8 meter are normal. When the GM_0 value is below or above these values this can negatively affect stability.

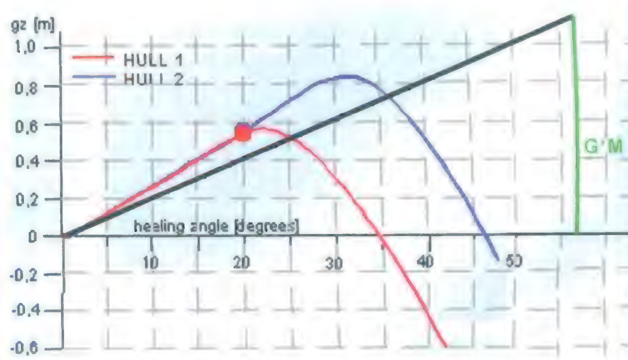
Ships with a small GM_0 have a long rolling period, which is more comfotable for people on board. But too small a GM_0, can result in capsizing after a colli-sion. Passenger ships have a small GM_0 value to achieve a long roll-ing period.

Ships with a large GM_0 are usually ships with heavy cargo, (steel, iron-ore) with the cubic capacity of the cargo-space hardly used.

When the cubic capacity is used completely - with grain or coal - the GM_0 will be smaller. The high accelerations due to a large GM_0 value are uncomfortable and could result in shifting of cargo.

To prevent too much stability after loading, the steel rolls are stowed in the lower hold and tween-deck, so to get the position of G is at an acceptable height, reducing the GM value. If all the steel is stowed in the lower hold, a short, abrupt rolling period could result, making life on board very uncomfortable and causing even damage to ship and equipment.





Higher ships have higher stability

Rollingperiod:
The period of time, needed to move from port to starboard and back to port, or counterwise. The rolling period varies from 30 seconds for passengerships to 8 seconds for wide ships, or ships with a low KG, due to heavy cargo low in the ship. Partly filled tanks (cargo, ballast, fuel), result in a virtual higher KG, and a smaller GM. This can be dangerous for small ships with a (too) small stability, but adding comfort on large ships with a (too) large stability.

Spray over the bow becomes ice when it is cold outside. The weight of the ice adds weight to the ship, at a not-wanted location. Under bad circumstances, Δ increases substantially, and GK becomes larger. Small ships with high and extensive rigging can easily come in danger in severe fog and bad freezing conditions.

2.5.3 Influence of Beam (Breadth) on GM

Ships with a large beam and shallow draught such as barges, have a large GM_0. Slender, narrow ships such as containerships or passengerships with a large draught, have a small initial stability. (Preferably in combination with a high freeboard).

As earlier mentioned, the initial stability GM_0, has nothing to do with the stability at greater angles. An extreme example is the floater of a fishing rod. This floater has a very small initial stability, but will never capsize.

2.5.4 Negative influences on stability

- heavy cargo on deck
- ice on deck, superstructures, masts, etc, due to freezing spray or fog (icing) in arctic regions.
- loading or discharging heavy pieces of cargo with the ships own cargo gear.
- the emptying of tanks low in the ships hull (double bottom tanks).
- free liquid surface(s).

The last item, the free-liquid-surfaces will be explained in part 3, in particular because this is the most important reason for stability problems, with a grat number of casualties.
In the design-stage all possible circumstances, such as loading and ballast conditions and adverse weather conditions have to be carefully reviewed and calculated with respect to stability.

3. Stability of Damaged Ships (Damage Stability)

For cargo handling longitudinal and Transversal bulkheads are unwanted features on (dry-cargo) ships.
Loading and discharging are hampered, and there are limitations for cargo with extreme dimensions.
Bulkheads are however necessary to limit the amount in-flowing water in case of a leakage, for instance after a collision.
In case in-flowing water could spread slowly and evenly through the ship, there would not be immediate danger to the ship. However, it is normal that in a collision case, the water flows fast into the ship, often from port to starboard or reverse. This creates a listing moment, with an impact depending on the quantity of the water and the distance the water can flow unobstructed, mainly in transverse direction. The severity of the situation is greatly depending on the distance it can flow transversally and the permeability of the space.

Permeability:
The extent to which a compartment can be filled with water is the permeability. The effect of incoming water on the stability will be:
- maximal if the compartment is empty (permeability = 1)
- minimal if the compartment is
- completely filled with for instance Styrofoam or a liquid. (permeability = 0).

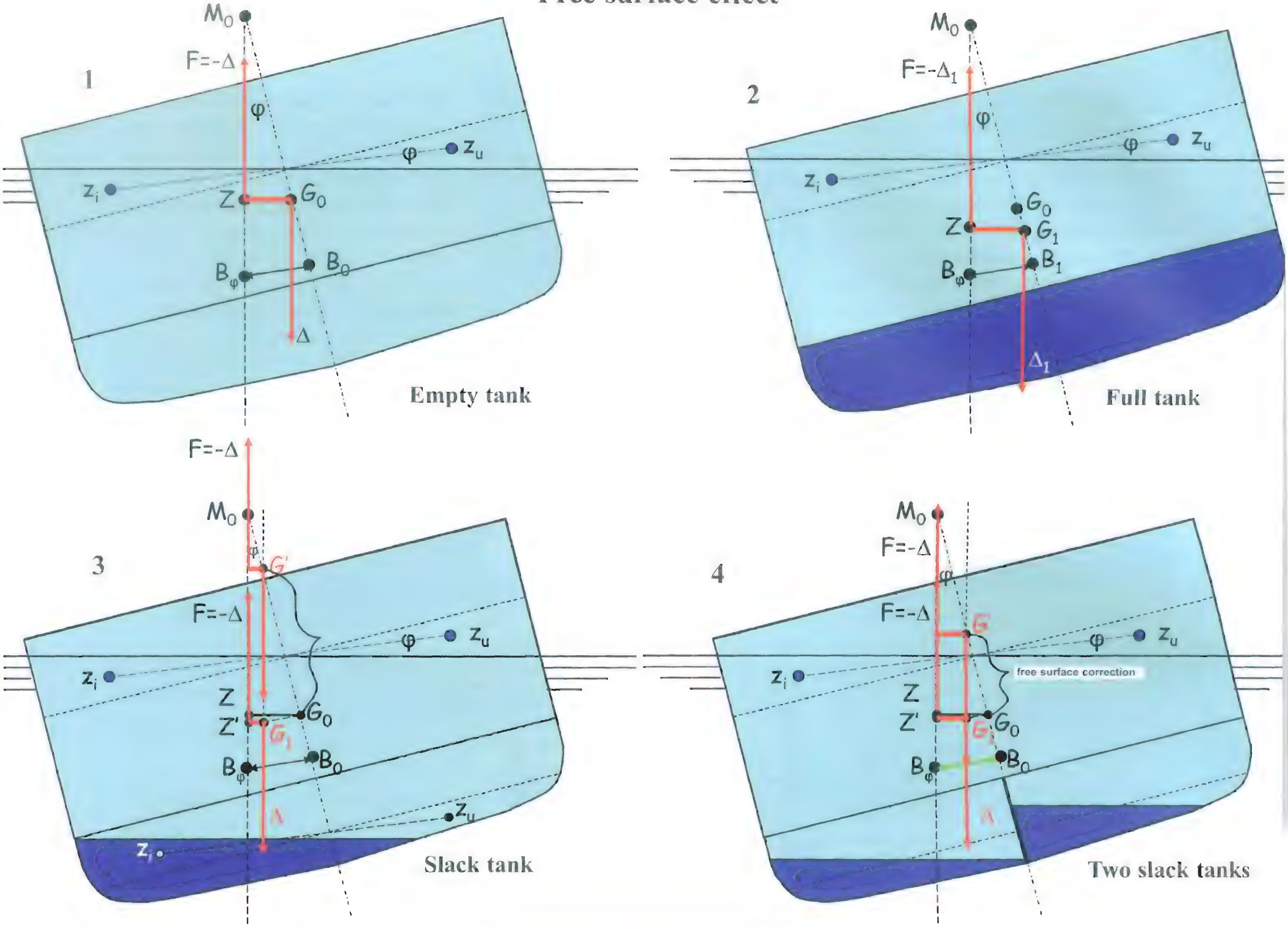
The permeability of an engine room is approximately 0.85. The higher the permeability of a compartment, the more volume can be occupied by leakage, the lower the remaining buoyancy.

The magnitude of a moment is determined by a force (weight) and the distance of that force to a fixed point. Example:

1. A child (30 kilos) and his father (60 kilos) are sitting on a seesaw. The distances to the turning point of the seesaw are 2 and 1 metres respectively. In spite of the difference in weight, both the father and the child exert the same moment on the turning point of the seesaw. (30x2 and 60x1 respectively). The seesaw is in equilibrium.
2. If a weight of 100 tons is moved 1 metre on a ship, the same effect on the trim can be achieved by moving 1 ton a hundred metres. In both cases the moment is 100 tm.

This illustrates how even a limited amount of liquid can cause a large moment on the ship if the liquid is allowed to move freely over the full width of the ship.

Free surface effect



Explanation of the abbreviations used in the above drawings:

G	=	*Center of gravity*
Bo	=	*Center of buoyancy (no list)*
Bφ	=	*Buoyancy by heel to port or starboard (external force)*
Bφ	=	*Buoyancy by list to port or starboard (internal force)*
M_o	=	*Initial metacenter*
GM	=	*Metacenterc height*
KM	=	*The height of initial metacenter above the keel*
K	=	*Keel*
Δ	=	*Displacement (D)*
F	=	*-Displacement (-D)*
φ	=	*heeling angle*
G_oG''	=	*virtual loss of GM*
GZ	=	*lever GZ, righting lever, the horizontal distance between the center of gravity and the vertical through the center of buoyancy.*
I	=	*moment of inertia of the free surface area of water on deck*

Moment of static stability
= Δ x GZ = Δ x GM sin φ

The distance that G moves depends on the length and width of the hold where the liquid is freely moving. De (virtual) movement of G can be calculated using the formula:

$$GG'' = \frac{I}{V} = \frac{\text{length tank} * (\text{breadth tank})^3}{12 * \text{vessel displacement}}$$

This formula shows clearly the influence of the width (to the third power) on the movement of G. See drawing 3. In drawing nr 4 the width of the tank is halved by a longitudinal bulkhead. The negative influence on the stability is considerably reduced and is only ¼ ($=2 \times (\frac{1}{2})^3$) of the original distance GG" In case 2 bulkheads are installed, i.e. 3 tanks beside each other, the effect will be reduced to 1/9 x GG"

Leakage of one or more compartments can have the following consequences:

- heel
- draught increase
- change in trim
- change in stability

A Ro-Ro ship which has capsized due to the free surface effect

Resulting from this weight increase at one side of the ship, a large list can develop in a short period of time. A ship can capsize in a few minutes. In recent years a number of fatal accidents occurred with Ro-Ro ships. Due to bow-door (ramp) failures seawater could enter freely into the ship.

Below a short explanation is following about the foregoing.

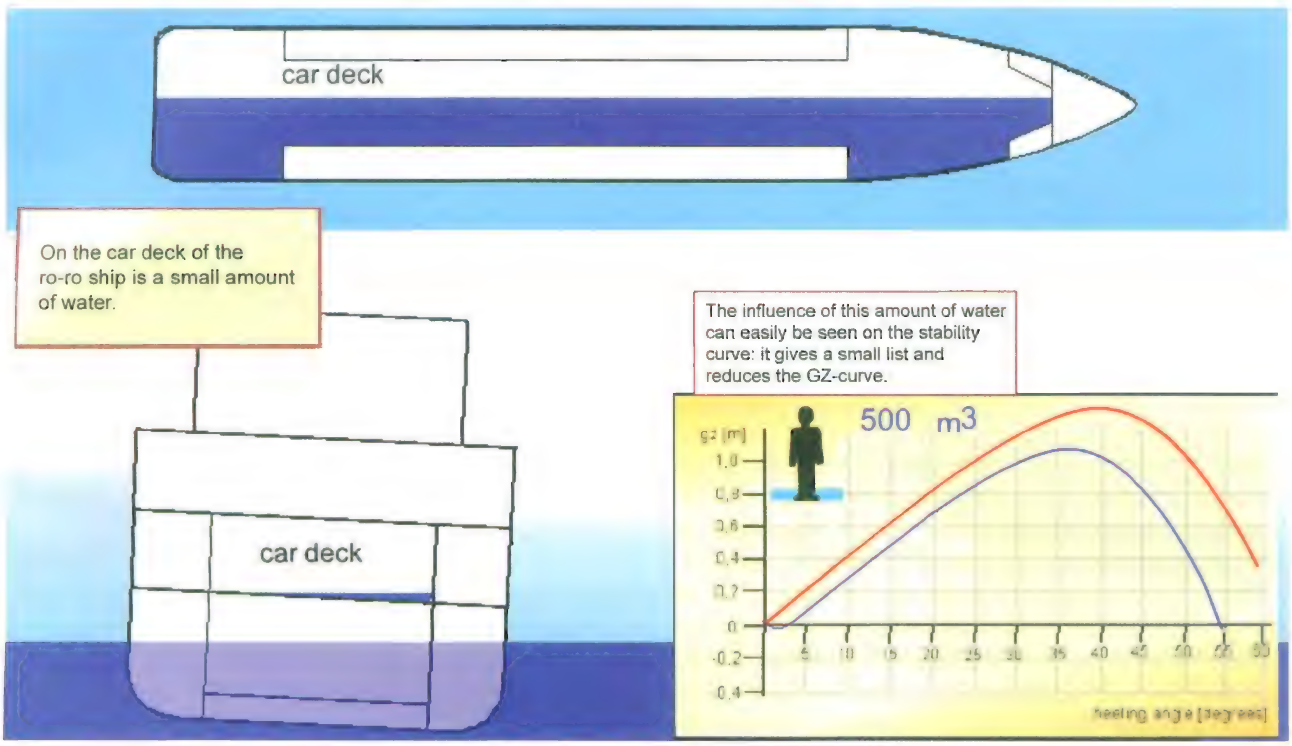
The water, flowing from port to starboard and vice versa has a free-surface effect. This can be seen as a weight, causing a heeling moment, working on the ship.

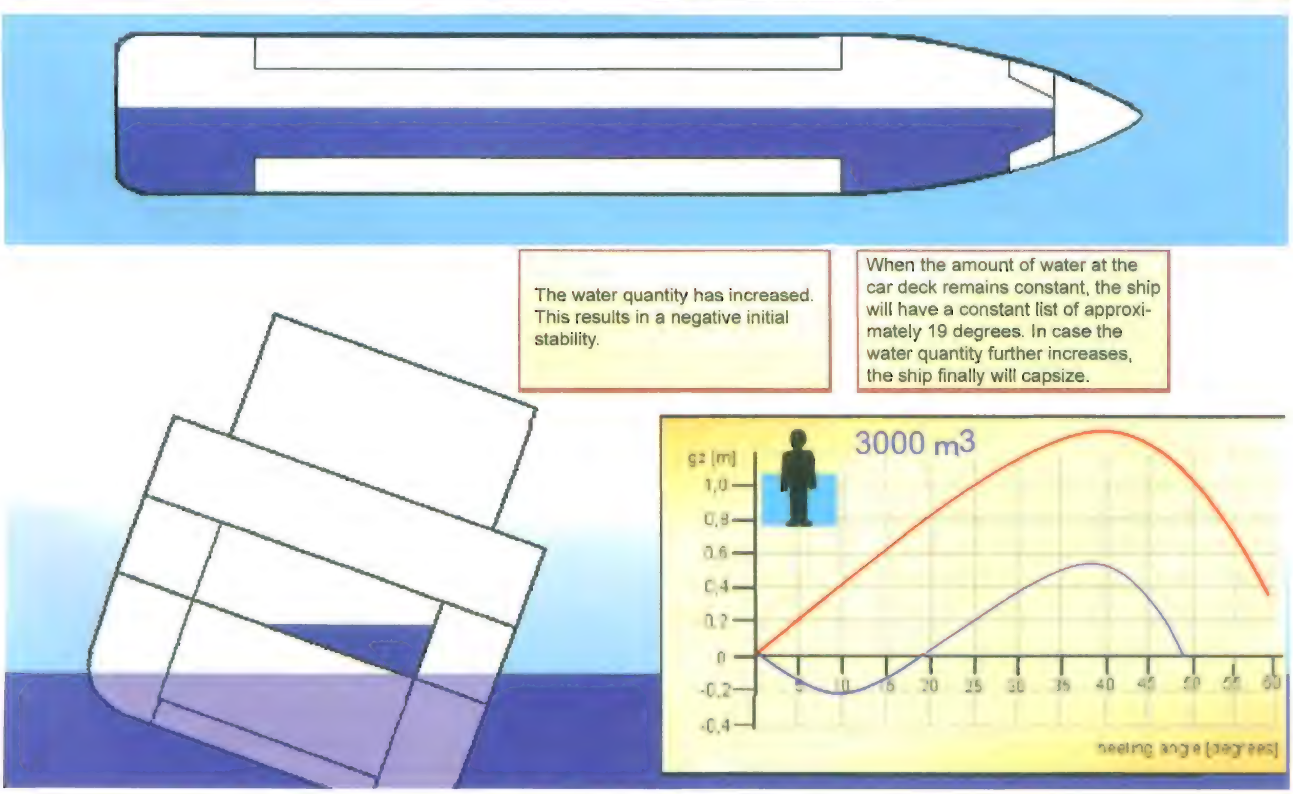
(1 m^3 = approx. 1 ton = 1000 kg.)

The effect a Free Surface Moment (FSM) can have on the stability of a ship will be (somewhat exaggerated) explained in the following figures.

NB: The list as drawn is a random picture of a complete roll of the ship. This roll, from port to starboard and back to port lasts only a few seconds, and can be caused by waves, wind, current, etc.

All these changes are acting from the moment the water in-flow starts.





The choice not to install bulkheads, for economical reasons, needs attention. At some types of ships the number of bulkheads is minimised in connection with hamper on loading and discharging, for instance at Ro-Ro ships and at ships for heavy cargo.
In tankers, the presence of bulkheads is needed to separate the various cargo-parcels and to reduce the influence of the free surface effect in the various, sometimes only partly filled tanks.

SOLAS vs IMO
The SOLAS-treaties must be incorporated into the national laws. The IMO-regulations are optional. However, in practice most nations also incorporate the IMO-regulations into their national laws.
In the past, many computational methods have been used to determine the number of bulk heads on a ship that are necessary for the safety. These are called damage stability calculations.

The drawings to the left show the effect of a free liquid surface in a car-deck of a Ro-Ro ship, and the effect of same at the stability curve.

4. Rules and regulations

It is obvious from the previous section that the free-liquid surface resulting from a leak in a compart-ment shall not pose a direct danger to the ship. The size of a compartment is therefore subjected to regulations as determined by the IMO-SOLAS-Convention.
There are three types of regulations:

4.1 Calculations of submersion and trim.

These calculations check if there is enough reserve buoyancy to keep the ship floating after a compartment has been completely filled with water*. The assumption was made that a ship sinks vertically as a result of the flooding. The reserve buoyancy is enough to compensate for the increased draught. So the number and the positions of the bulkheads were related to the buoyancy and the reserve buoyancy**. After the Titanic disaster these calculations were implemented in the first issue of SOLAS. The experiences of the Second World War proved that these SOLAS-rules were not adequate because of the assumption that a ship sinks vertically. Instead, many ships first capsized before sinking.

*The reason was that a ship with flooding compartments should not submerge below the maximum immersion line. This is an imaginary line on the hull that runs 76 mm below the bulkhead deck. The bulkhead deck is the deck above which the bulkheads are not water-tight. This deck should remain above the waterline across its entire length, thus preventing flooding from one flooded compartment into others resulting in the sinking of the ship. It is assumed that the ship sinks vertically, that is, without heel.

**The maximum distance (floodable length L) between two watertight bulkheads is calculated for a large number of points P going from aft to the forward. Every space that is created in this way has the point P at half this length. The volume of these compartments is chosen in such a way that the ship has enough spare buoyancy after the compartment has filled up. The ship submerges a little but the bulkhead deck remains above the maximum immersion line. In order to get a quick view of the maximum distance between the watertight bulkheads across the entire length of the ship, the lengths L are plotted vertically against the points P. The resulting curve is called the Curve of Floodable Lengths

A (shortened) calculation of the floodable lengths, beginning in the aft perpendicular and the resulting bulkhead graph is shown below. The table and the curve are for the yacht on the picture.
Depending on the regulations, the ship should be able to survive a one-compartment damage or a two-compartment damage.

Distance from APP in metres	Floodable length in metres
00.00	20.32
05.00	10.32
10.00	11.35
15.00	13.42
20.00	17.56
25.00	17.09
30.00	11.54
35.00	09.14
40.00	08.96
45.00	14.06
50.00	24.02
53.75	31.52


Produced by M. Straten, Nijmegen

Floodable length curve

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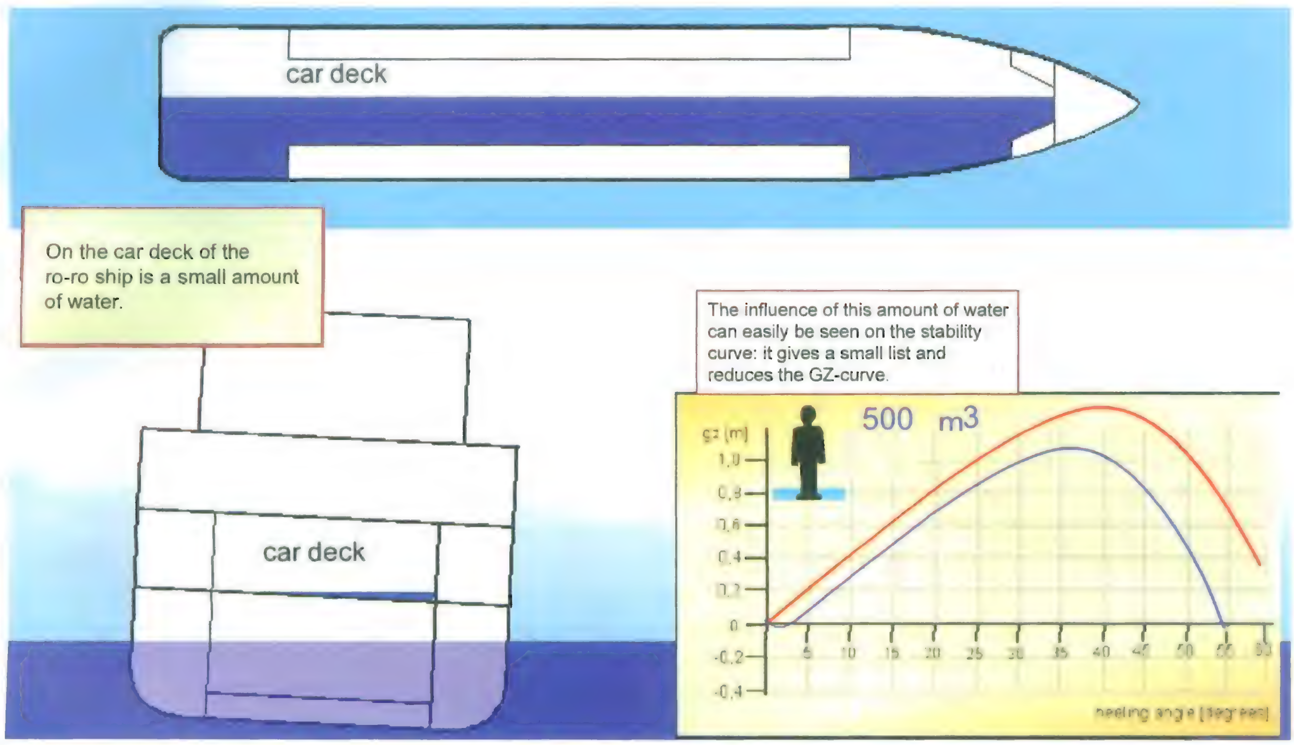

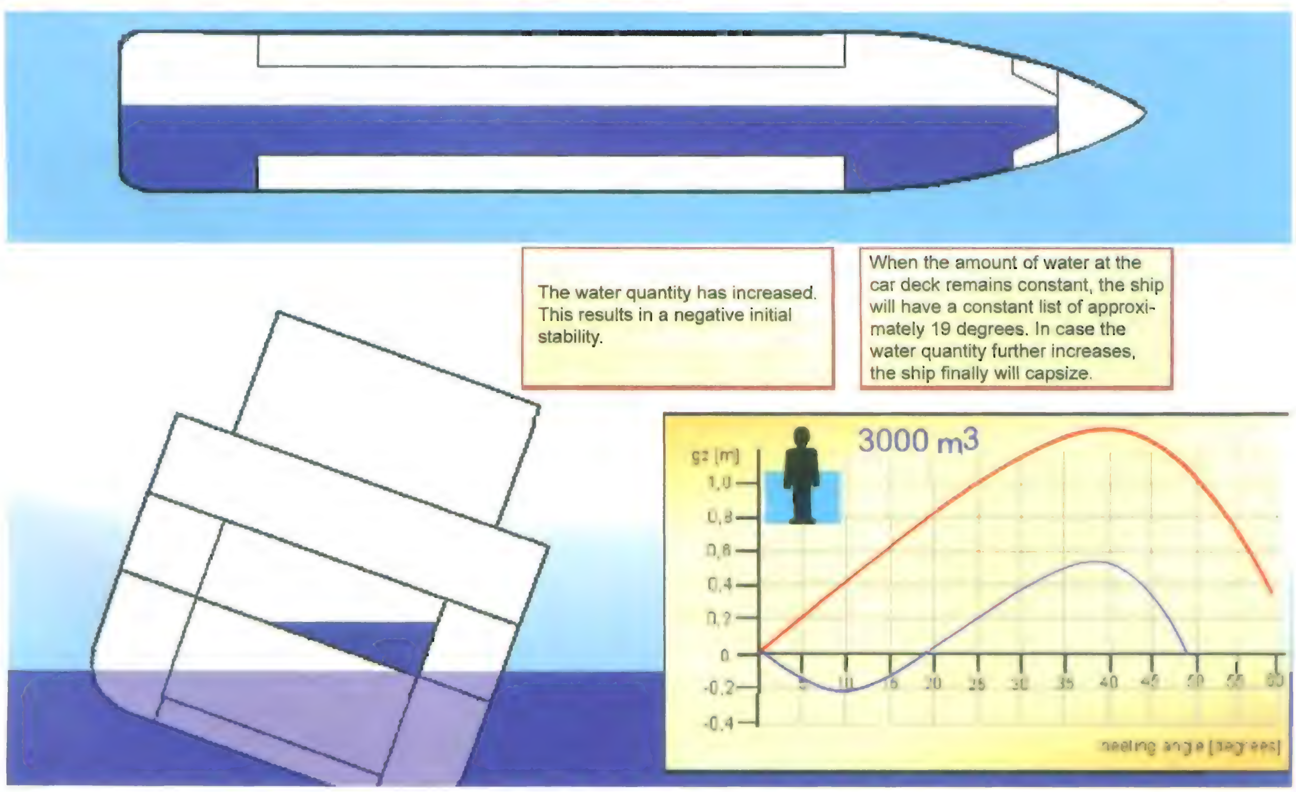

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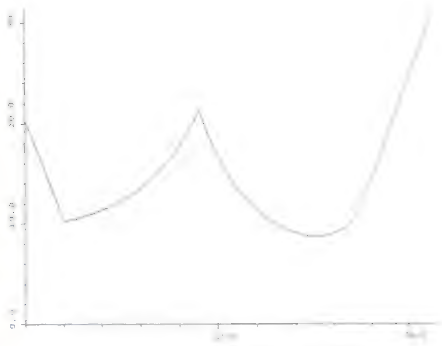

Floodable length curve

A one-compartment-ship can survive the (accidental) flooding of one compartment. Regardless which compartment.

A two-compartment damage can occur if the ship is struck at a bulkhead separating two compartments. The combined length of the two compartments should then be smaller than the floodable length to survive the damage.

4.2 Calculation of Floodable Lengths.

(Trim and stability in case of a damage assuming certain well defined types of damage)
A drawback of the method described in a) is that a possible heel is not taken into account. The method described here to determine the number and positions of the bulkheads does take the loss of stability into account and also assumes some well-defined types of damage. These calculations are called deterministic flooding calculations.
A drawback of this method is the exact definition of the damage. A ship that is designed by this method can live up to all the demands, but still sink if the damage is 1 cm bigger than the assumed damage.

4.3 Probabilistic damage calculations

(Calculations of the chance of surviving in case of damage)
This method attempts to apply the possibilities that the damage is not the same throughout the length of the ship. A probability is assigned to every type of damage, as is the probability of surviving this damage. The sum of all these probabilities is a number between 0 and 1 and represents the chance of surviving in case the ship is damaged. The regulations derived from this method also include a minimum survival chance. These probabilistic damage calculations currently apply to:

- passenger Ships (IMO resolution A265) as an alternative to the SOLAS rules (resolution A265 still encompasses some deterministic rules).
- cargo Ships with dry cargo, longer than 80 metres (measured over the closed hull).

In order to estimate the center of gravity of the flooding, a number of uncertain parameters are of major importance.
For instance:

- what positions does the water occupy, especially in rooms with an irregular shape?
- trim, list
- the possibility of trapped air-bubbles.

5. How to take damage stability into account on board.

The stability must be calculated for every voyage a ship makes, and of course the stability has to fulfil the various rules and regulations. The weight distribution can differ per trip as can many other parameters. Factors that are of importance to the damage stability are:

- kind of cargo (permeability)
- wing and double-bottom tanks; filled or empty
- does the liquid stay in a damaged tank or does it flow out?

A lot of calculations and thorough knowledge of rules and regulations are required in order to determine the influence of all these factors. Furthermore, the chances of survival (probabilistic calculations) should also be incorporated into these calculations. In practice it is impossible to execute the calculations without the aid of a computer.

A computer with a loading pro-gramme, capable and programmed to calculate longitudinal strength, shearforce, intact- and damage stability is generally required on all ships longer than 65 meters to make the required calculations After all the weight data have been fed into this computer, the position of the center of gravity (G) above the keel (K) can be calculated.

The regulations concerning damage stability usually only mention the maximum allowed heeling angles. Sometimes the possibility of counterflooding is incorporated.

Counter-flooding is the deliberate filling of a compartment or tank at the opposite side of the ship to offset any heel resulting from flooding due to damage. Often used in passenger liners, even automatic systems are used.

The maximum KG is the number that indicates how high point G may be above the keel in agreement with the requirements made in SOLAS with regard to the stability of a ship.

NB: the maximum KG depends on the draught/displacement and these factors must be taken into account.

Car deck of a Ro-Ro with doors to reduce the extend of any liquid flooding the deck.

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Two tankers at a loading and discharge berth. The VLCC on the right is equipped for loading from a FPSO, as can be concluded from the deckhouse on the bow. The smaller tanker left is probably a combinationtanker, not only for crude oil, but also for products, as can be concluded from the external deckstiffening.